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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

EXPLANATION OF SHEET 126.

THE GEOLOGY OF THE COUNTRY BETWEEN NEWARK AND NOTTINGHAM.

By

G. W. LAMPLUGH, F.R.S., W. GIBSON, D.Sc.,
R. L. SHERLOCK, B.Sc., AND W. B. WRIGHT, B.A.

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PREFACE.

THE original geological survey of the area was made on the Old Series one-inch map; the greater part, on Sheets 71 N.E. and S.E. being surveyed by W. T. Aveline, Edward Hull, and T. R. Polwhele; while the eastern portion, on Sheet 70, was surveyed at a later date by W. H. Holloway.

This Memoir describes the Geology as depicted on Sheet 126 of the New Series Colour-printed Map. While the Memoir was in the press, the Ordnance Survey has brought out a new edition of the Sheet, which has been used as the basis for the Geological Map. A few slight discrepancies between the spelling of place-names in the Memoir and on the Map have arisen from this cause.

The recent re-survey on the 6-inch scale, on which the new map is based, was begun under the superintendence of Mr. C. Fox-Strangways. Upon his retirement in 1904 the work was continued under the superintendence of Mr. G. W. Lamplugh, who has acted as editor to the present Memoir.

Although the Coal Measures reach the surface only at one place within the map, covering not nearly a square mile, they have been proved to extend beneath the newer formations over the greater part of the area, and collieries are already working in the eastern part of the district. As the underground extension of the Coalfield is likely to prove of great economic importance in the future, all the available information regarding it has been collected and discussed by Dr. W. Gibson.

The late Mr. James Shipman contributed very largely to our knowledge of the geology of the district referred to in this Memoir, not only in published papers, but also by keeping manuscript records of temporary exposures which he had visited. These records have been acquired by the University College, Nottingham, and were placed at our disposal through the kindness of Professor Carr.

We have also received much assistance from Mr. G. E. Coke, M.Inst.C.E. and M.E. of Nottingham, and from numerous colliery proprietors, engineers, and others, to whom acknowledgments are made in the text.

J. J. H. TEALL,
Director.

Geological Survey Office,
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43. N.E., N.W., S.E., S.W., by W. B. Wright.
44. N.E., N.W., S.E., S.W., by W. B. Wright.

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GEOLOGY

OF THE COUNTRY BETWEEN

NEWARK AND NOTTINGHAM

CHAPTER I.

GENERAL DESCRIPTION.[1]

Introduction.

The River Trent, whose course runs obliquely across the middle of the map from south-west to north-east, dominates the physical structure of the country included within Sheet 126 (New Series) of the Geological Survey Map to be described in the present Memoir. The outlines of this sheet are shown in the small sketch-map, Fig 1 (p. 3). The city of Nottingham lies within the south-western corner of the sheet, the ancient borough of Newark at its north-eastern margin, Newstead Park at the north-western corner, and part of the Vale of Belvoir around the villages of Bottesford, Muston and Redmile at the south-eastern corner. Southwell, famous for its ancient minster, and now the site of a bishopric, falls just within the northern edge of the map, and the small market town of Bingham lies three miles within its southern border. A string of populous villages ranges along the Trent Valley between Nottingham and Newark, and other villages are dotted over the rich agricultural country north-west and south-east of the Trent, while the overflowing population of Nottingham has tended to spread northward up the valley of the Leen, which joins the Trent near the western margin of the map. Nottingham, the second city of the Midlands in size, is an important manufacturing centre. At Newark the population draws its support largely from the malting, plaster-making, and engineering industries. The rest of the country is primarily agricultural.

The greater part of the area lay within the Quarter-sheet 71 N.E. of the Old Series map, on which the work of the first geological survey was published in the year 1858 (with some

[1] By G. W. Lamplugh.

additions in 1879), and smaller portions were contained in the adjoining Quarter-sheet 71 S.E., and in the whole Sheet 70. This first survey was made on the Ordnance maps of the scale of 1 inch to the mile, which at that time were alone available. The recent work has been carried out on the Ordnance maps of the 6 inches to the mile scale; and the 'superficial' deposits, which were not included within the scope of the original survey of Sheet 71, have now been mapped out, along with the 'solid' formations. The work has been reduced to the 1 in. scale for publication on Sheet 126, but manuscript copies of the 6 in. field-maps have been prepared, and are available for public reference at the London office of the Geological Survey.

As Nottingham lies so close to the margin of the sheet, it is intended shortly to publish a special Nottingham Map, with an accompanying special Nottingham Memoir, which will include parts of four of the present numbered sheets with the city of Nottingham placed centrally, as it is believed that this arrangement will prove more convenient for local purposes. It is to be remembered, however, that the present 'Newark and Nottingham' map, Sheet 126, is known alternatively as the 'Nottingham Sheet' in the Ordnance Survey Catalogue, so that care must be exercised in distinguishing between this sheet and the forthcoming special Nottingham Map.

Physical Features and Geological Structure.

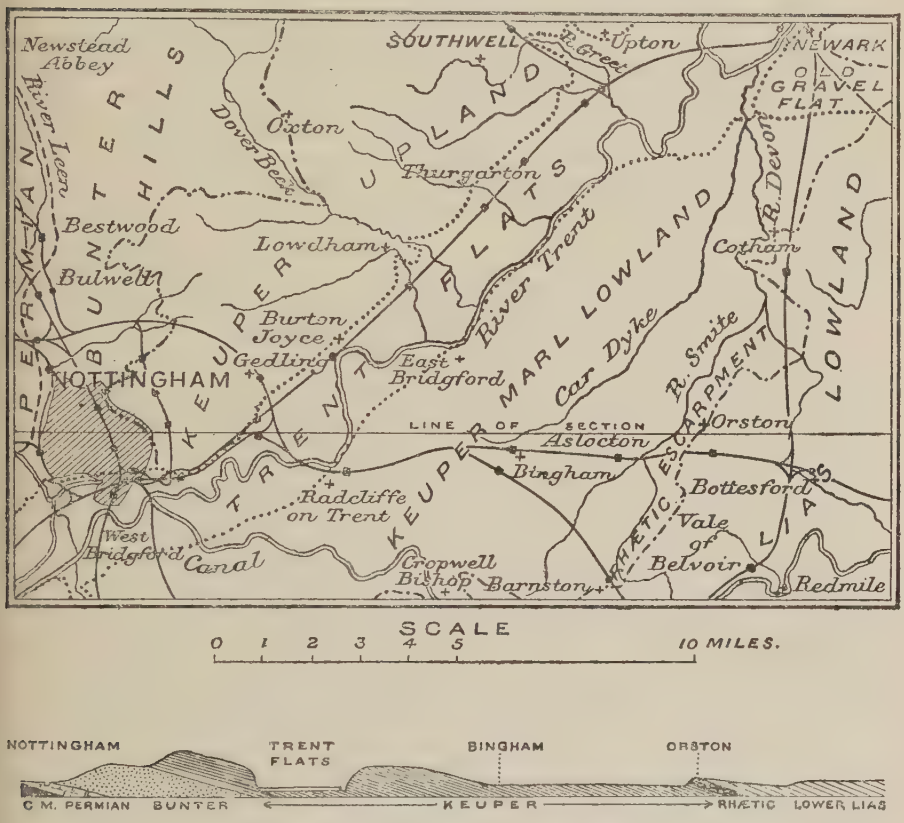
In its general structure the country is a low plateau, much dissected by the Trent and its tributaries. The highest ground within the map occurs in the hilly north-western portion, where small tracts in Newstead Park and at Cockpit Hill, near Woodborough, rise just above the 500 ft. contour-line; southward and eastward the average summit-levels decline gradually, ranging between the 400 ft. and 300 ft. contours north-west of the Trent, but only in two places rising above the 200 ft. level on the south-east side of the river.

In spite of its low general level the country shows considerable surface-relief, the readily perishable character of the strata, and the comparative vigour of its drainage system tending to produce steep slopes along the lines of drainage, and to permit slight differences in the resistant quality of individual beds to develop somewhat bold features at their outcrops.

The Trent occupies a singularly straight-sided trench-like valley with a broad flat floor of alluvium, upon which the river meanders greatly, though hanging principally toward the south-eastern side. The small tributaries which flow into it from the north —of which the more important are the River Leen, Dover Beck, and the River Greet— have their courses nearly at right angles to the main river, their average direction being between south and south-east, and the courses of these streams are approximately in the direction of the dip of the Triassic rocks, except in the case of the Leen, which runs southward along the strike

of the Permian and Trias junction. The chief tributary on the opposite side of the Trent, the Devon, has a general north-north-westerly course, but its principal feeders, the Smite and Car Dyke, flow north-east, parallel to the Trent, or in the direction of the strike of the rocks (see Fig. 1). This difference gives rise to a marked contrast between the features of the country on the opposite sides of the Trent, the ground on the north-western

FIG. 1. SKETCH-MAP AND SECTION OF SHEET 126.



side being an irregular plateau dissected by numerous rather steep-sided transverse valleys, while on the south-eastern side the ruling features are the low smooth longitudinal ridges, between which lie broad shallow depressions lined with alluvium. It is possible that the Glacial conditions to be subsequently discussed have had a determining influence upon the present course of the Trent in this district.

Before entering upon the fuller description of the geological formations, we may here briefly consider their more salient characters, and their influence upon the shape of the country.

Carboniferous: *Coal-measures* (for full account see Chap. II.).—The oldest rocks that come to the surface within this map are the Coal-measure shales, but these only just enter it at one place in a shallow depression reaching to the Leen valley at Radford, on the north-western outskirts of Nottingham. All along the western side of the map, however, the Coal-measures are found under a comparatively thin covering of the newer formations, and their coal seams are mined in several collieries. They shelve gradually deeper eastward, but have been reached in deep borings through the overlying rocks as far east as Thurgarton, and are probably continuous under the greater part of the country up to the eastern edge of the map (see pp. 23–5).

Though so little in evidence at the surface, and therefore so unimportant in their structural effect upon the ground, the accessibility of these Coal-measures within the area of the map, and at their main outcrop immediately to the westward of it, has been the predominant factor in the great industrial development of the district.

Permian: *Magnesian Limestone, and Marl* (see Chap. III.).—Like the Coal-measures beneath them, these rocks are exposed only at the western margin of the map, where they occupy narrow strips that represent the fringe of their broader outcrop in the next sheet (No. 125). They rest with strongly-marked unconformability upon the Coal-measures, but are conformable to, and closely interlinked with, the Triassic rocks, under which they disappear eastward. From the deep borings referred to above, we know that the Permian rocks are prolonged eastward beneath the Trias, being carried gradually to greater depths owing to the prevalent south-easterly dip, in which all the strata above the Coal-measures participate. West of Nottingham, however, they die out before reaching the Trent and are absent underground in the south-western part of the map.

The lowest member of the series is the Magnesian Limestone, which, after extending in a broad continuous belt from the coast of Durham, has become much attenuated before it enters the present map, and, still diminishing, reaches its southerly termination at Nottingham. Its thickness at outcrop in this district nowhere exceeds 40 ft.

The red Permian Marls, which overlie the Magnesian Limestone, are scantily exposed in this map, though well seen in the brickyards at Bulwell, slightly beyond its western margin They average about 20 ft. in thickness at this place, but disappear southward before the limestone terminates. They occupy the upper part of the broad shallow valley of the Leen, while the Magnesian Limestone forms a low platform rising gently westward from this hollow.

Trias (see Chap. IV.)—With the exception of the above-described narrow strip at its western margin, the whole area of the map north of the Trent is covered by Triassic strata, and the upper portion of the series also extends over a wide tract south of

the river, so that more than three-fourths of the map is occupied by the Triassic deposits. They are separable into two major divisions, which correspond roughly to marked differences in composition, the lower or Bunter division consisting mainly of sands, soft sandstones and pebble beds, while the upper or Keuper division is made up principally of red clays or marls, with some subordinate sandy beds toward the base. This difference in the lithological character of the two divisions produces a corresponding difference in the topographical features at their respective outcrops. It is customary to class the Rhætic formation also with the Trias, though in this district it is more nearly akin in lithological composition and in mode of origin to the overlying Lias than to the underlying Keuper.

Bunter.—The semi-coherent sandstones and pebble beds of this division form the basis of the dry hilly country in the north-western corner of the map between Newstead Park and Oxton, the southern part of the ancient Forest of Sherwood, so famous in legends of mediæval outlawry. South of Bestwood, the outcrop of these beds is much narrower, and the general level of the country is lower, but the topographical features remain the same; the irregular range of dry sandy hills being continued up to the valley of the Trent at Nottingham. The greater part of the city itself is built upon the pebbly sandstones of the Bunter, which terminate in steep bluffs overlooking the broad river flat and culminating picturesquely in the lofty crag crowned by Nottingham Castle.

The incoherent Lower Mottled Sandstone constitutes the lowermost part of the Bunter; and the overlying Pebble Beds, owing to their superior durability, tend to form a bold escarpment rising steeply above the gentler slopes of the sandstone which lead down to the low ground occupied by the Permian strata. It may often be noticed also that, within the area covered by the Pebble Beds, subsidiary features are caused by the presence of bands or lenticles in which pebbles are particularly abundant in the sandy matrix.

The thickness of the Bunter beds is variable, being greatest in the northern part of the outcrop and diminishing southward. In a deep boring at Grimesmoor, near Woodborough (p. 117), which penetrated the whole of the division, the total thickness of the Bunter is about 430 ft.; at Gedling (p. 102) it is 385 ft.; and at the 'Spinney' boring south of Wilford (p. 18) it is 234 ft.

Keuper.—An impersistent band of pebbly conglomerate, varying when present from a few inches to a few feet in thickness, occurs at the base of the Keuper series, but is too thin and too closely allied in lithological character with the underlying Bunter to develop an independent surface-feature or to be shown separately on the map. The 'Waterstones' which overlie this 'Basement Bed' consist of thin flaggy alternations of soft reddish, brown or grey sandstone with dull red or greenish marl. In the westerly part of their outcrop these strata have an average thickness of about 80 ft., which increases eastward to 100 ft. or more, and is apparently still greater in their south-easterly

prolongation beneath the overlying marls (p. 44). They are sharply differentiated from the Bunter by their loamy texture and regular stratification, but upward they gradually lose their distinguishing characters and merge imperceptibly into the marls, so that their upper boundary is always indefinite. Being readily disintegrated, these 'Waterstones' at their outcrop form long concave slopes, which lead up to a steeper rise marking the escarpment of the marls, and in this fashion they follow this escarpment uninterruptedly from Halam and Southwell to Nottingham.

The Keuper Marl is the predominant formation of the map, and occupies a broad belt from 5 to 8 miles in width, striking diagonally from north-east to south-west across the middle of the sheet, on both sides of the River Trent (see Fig. 1). It consists of regularly stratified red calcareous clay or very fine silt, with subordinate greenish-grey bands, and occasional flaggy layers of hard calcareous sandstone, known as 'skerry.' The topmost beds of the division are of a greyish-green colour—hence known as the 'Tea-green Marl'—and at a short distance below this horizon the marls usually include irregular bands of gypsum, which is also distributed more sparingly, in veins and strings, at lower levels. In this district the Keuper Marl attains an average thickness of about 700 ft., and dips south-eastward at a low angle, rarely exceeding 3 degrees.

The hard skerry bands, though not often more than a foot or two in thickness, have a considerable effect upon the outlines of the country, being much less perishable than the marls, and therefore giving rise to comparatively bold surface-features. Hence the steep flat-topped escarpment of the marls and the little plateaux between this escarpment and the Trent Valley owe their characters mainly to the presence of skerries (which are indicated on the map); and the alternation of broad shallow troughs and low ridges in the lower country south of the Trent is due to the same cause.

These sandy beds are almost absent from the uppermost portion of the marls; and as the strata of the gypsiferous belt perish readily, a broad hollow has been developed in the upper part of the series, edged on the south-east by the bank-like escarpment of the overlying Rhætic and Lias.

While the Bunter probably represents the deposits of large rivers brought down into current-swept land-locked waters, the Keuper appears to have been deposited in the quiet waters of a large salt lake or inland sea, at a time when desert conditions prevailed over the surrounding land.

Rhætic.—Overlying the Tea-green Marl of the Keuper with a sharp, though not markedly unconformable, junction, we find a thin series of deposits containing fossils of a peculiar type which are remarkably persistent in beds of similar character at this horizon throughout England. The lowest part of these Rhætic beds consists of black shale, and this is overlain by grey shale and paler clays with nodules and a thin impersistent layer of hard brittle limestone at the top, the thickness of the whole

series being about 30 ft. The fossils are marine, but the mollusca belong to a limited number of species, mostly dwarfed, as though the conditions had not been favourable to a purely marine fauna, such as that found in the overlying Lias. The Rhætic, therefore, is interpreted as marking the first inroads of the sea upon the region in which Triassic conditions had previously prevailed.

In the present map these Rhætic deposits occupy a low but very definite escarpment, capped by the lowermost beds of the Lias. The feature may be traced southward from Beacon Hill at Newark, past Cotham and Orston to Granby, and thence westward through Barnstone to beyond Cropwell Bishop.

Lower Lias (see Chap. V.).—The persistent though gentle south-easterly dip of the strata brings in the Lower Lias on the comparatively low ground in the eastern and south-eastern part of the map, the lowest beds setting in on the brow of the Rhætic escarpment as above described. The series consists of greyish blue shale, weathering at the surface to a tough brownish clay, interstratified with flaggy bands of argillaceous limestone.

In the lowermost part of the series these limestone bands are particularly abundant, and in places predominate over the shales: but in the higher beds they are widely spaced among the thick shales, and are comparatively unimportant, though, like the 'skerries' of the Keuper, they often give rise to low ridges striking along their outcrop. The lower limestones are of value as a material for hydraulic cement, and are extensively dug for this purpose at Barnstone. One of the strong layers higher in the series represents the horizon of the celebrated ironstone of Frodingham in Lincolnshire, which has here dwindled into a thin band of ferruginous limestone.

The fossils of the Lower Lias show that it is a marine sediment; and by their numbers and diversity they enable us to separate the formation into subdivisions or 'zones' (p. 59). Of these zones, only the three lowest fall within the present map, the thickness of strata represented by them being about 370 ft.

Superficial Deposits: *Glacial Drift* (see Chap. VI.)—So far as the 'solid' rocks are concerned, the Lower Lias constitutes the latest formation within the map, any newer Mesozoic strata which may have originally covered the area having been stripped away by long-continued erosion. The 'superficial' deposits which occur in patches overlying the 'solid' rocks all belong to comparatively recent periods, when the geological structure of the district was already essentially similar to that of to-day, and the featural modifications due to these deposits are of minor consequence.

Of these superficial deposits the oldest are the Glacial drifts, accumulated at a time when arctic conditions ruled in this country. Considering the great extent and thickness of the Glacial deposits in many parts of the Midland counties, it is remarkable that in the present map their area is restricted to a

few patches of stony loam east of Bingham (shown with some hesitation as Boulder Clay on the map), along with some isolated patches of gravel occurring mainly near the western border of the map and near Newark, while the rest of the ground, particularly the upland north-west of the Trent, is practically driftless. Whether this denotes that the driftless area was never covered by the ice-sheets of the Glacial period, or only that the ice in its passage left here very little detritus, which has since been removed by denudation, is still uncertain. In favour of the latter supposition is the fact that the patches of drift above referred to usually occupy relatively high ground, which they appear to have in part protected from the general weathering that has lowered the adjacent tracts.

Late-glacial and Post-glacial (see Chap. VII.).—The deposits later than the Glacial drift are always definitely associated with the existing valley system, and bear evidence to a continuous land-drainage since the close of the Glacial period. They consist of river-gravels, loam, and other alluvial sediments occurring either on the valley-floors or in irregular terraces along their flanks.

The oldest gravels probably belong to the closing stages of the Glacial period, when the rivers were subject to seasonal floods of powerful volume, and they are therefore differentiated on the map by a distinctive symbol. Gravels of this character line the south side of the Trent flats between West Bridgford and Radcliffe, and form a well-marked terrace or low plateau running eastward from Newark.

The Trent subsequently excavated its broad trench deeper into the Keuper Marls, and continued to bring down huge masses of gravel from its higher reaches, which were spread in sheets and low banks over the whole of the valley-floor. These gravels now occupy the surface over large areas of the Trent flats, but they are partly buried under later accumulations of loam and silty clay deposited by the river and its tributaries in more recent times, when all the streams had been reduced in volume, and were unable to transport so great a load as formerly. The gravels of the Trent are thus separable from the later alluvium, and are separately shown on the map.

The chief alluvial tracts other than those of the Trent are the peaty and silty flats, formerly swamps, which occur along the course of the River Devon and its tributaries in the eastern and south-eastern part of the map. These flats have been reclaimed by artificial drainage; but even yet, portions of them are occasionally flooded in wet seasons.

Table of Formations.

The following formations, briefly described in the foregoing pages, are represented on the map:—

Superficial Formations.

	Recent	Alluvium.
Pleistocene	Post glacial	River-gravels.
	Late-glacial (Fluvio-glacial)	Older river-gravels.
	Glacial	Sand and gravel. / Boulder clay.

Solid Formations.

Jurassic	Lower Lias	Shaly clays with thin limestones.
Triassic	Rhætic	Black and grey shales.
	Keuper Marl	Red and variegated marls with thin sandy bands.
	Keuper Waterstones	Thin sandstones and marl
	Bunter Pebble Beds	Soft sandstone with pebbles.
	Lower Mottled Sandstone (Bunter)	Red and variegated soft sandstone.
Permian	Permian Marl	Red marls.
	Magnesian Limestone	Dolomitic limestone.

Strong Unconformity.

Carboniferous	Coal-measures	Grey shales and sandstone

CHAPTER II.

UPPER CARBONIFEROUS.[1]

Coal-measures.

The Coal-measures, entering the district as a narrow prolongation from the coalfield to the west, consist of pale-grey clays and thin-bedded sandstones belonging to a horizon about 60 yds. above the Top Hard Coal. The area of their outcrop is less than the half of a square mile. They are only to be seen in a small stream north of the canal lock, west of Radford, being elsewhere concealed beneath the superficial deposits of the Leen Valley. An examination, by the late James Shipman, of some artificial excavations proves the Coal-measures to extend beneath the alluvium of the Leen Valley as far north as Albert Road, and to terminate southward some distance to the north of the gasometers at Old Radford, where he notes the occurrence of pale-grey and red clays belonging to the Coal-measures beneath 32 ft. of Bunter Sandstone.

Although the area of exposed Coal-measures is so small, the colliery explorations at Gedling and Clifton, and in the Leen Valley, prove a considerable extension of the Coal-measures beneath the secondary rocks to the south and east. Borings have further shown that the Coal-measures underlie the Secondary rocks over practically the whole area included in Sheet 126, and for an unproved distance to the south and east.

Since the shaft-sections and borings prove the existence beneath the red rocks of nearly the entire sequence of the midland Coal-measures, it will be advisable first to give this sequence so far as it has been proved in the Derby-Notts coalfield, and to mention briefly the characters by means of which one portion can be distinguished from another.

The division of the Coal-measures into (1) a Red-and-grey Series, containing only a few unimportant and thin seams of coal, and (2) a Grey chief coal-bearing Series, with numerous and thick seams, holds good not only for Nottinghamshire, but for every coalfield in the Midland counties.

The subdivisions established in the Red-and-grey Series can be readily distinguished by their individual lithological or palæontological characters. Thus *Pecopteris arborescens* is confined to the Newcastle and Keele Groups. The Etruria Marls have so far proved to be without distinctive fossils, but the bands of green grits are restricted to this group, and possess characters not met with at any other horizon in the Coal-measures, being made up of fragments mostly of igneous origin,

[1] By W. Gibson.

set in a matrix resulting from the decomposition of similar material.

In the Grey chief coal-bearing Series the character of the strata remains very much the same throughout, so that, in comparing one section with another, geologists and mining engineers have chiefly relied on the order of occurrence and nature of the coal-seams. Fossil evidence has been almost entirely neglected; but the examination of recent sinkings and borings, and of sections in the exposed coalfield, show us that the fossils make their appearance in the same order as in the North Staffordshire coalfield, and that four marine bands occupy definite positions in the sequence. The position of these bands where noticed, or where they might be expected to occur if looked for, is indicated in the accompanying table giving the general sequence (p. 12).

Especial reference must be made to the marine band a short distance above the Clowne Coal (see p. 14). This bed has been traced through the entire length of the coalfield. It contains a specialised and generally rich fauna, and invariably rests on a hard blue argillaceous limestone ("cank" of the miner) with *Productus* and *Chonetes*. The marine band above the Alton Coal has also been traced long distances on the western margin of the Derbyshire Coalfield, and is known to be present above the Halifax Hard Bed Coal of Yorkshire. The marine band, 300 ft. above the Deep Hard Coal, has been met with at only two localities in the exposed coalfield, so that less reliance must for the present be placed upon it. Among the lamellibranchiata, other than those which occur in the marine beds, the genera *Carbonicola* and *Anthracomya* serve a useful purpose. Thus *Carbonicola robusta* never ascends above the Top Hard Coal; while *Anthracomya phillipsi* has not been met with below this coal.

In the following account of shaft sections, we commence with the older collieries situated on the west and proceed to the newer explorations in the east.

Collieries.

Newcastle and Radford Collieries.—In the record of the shaft-section of the Newcastle Colliery it is difficult to judge, from the description given (see Plate I.), whether the sinking commenced in Bunter or in the Magnesian Limestone. The conglomerate, 6 ins. thick, at a depth of 65 ft., would appear to be the basal breccia of the Permian; so that if any Bunter be present, it must be very thin at this point. The Top Hard Coal was reached at a depth of 406 ft. from the surface. A thin seam known as the Combe Coal, which lies a few inches above the Top Hard in the northern part of the Leen Valley, is here separated from it by 3-9 ft. of strata, in which Mr. Shipman notes[1] the occurrence of numerous upright and some prostrate fossil trees. A wash-out was met with in the workings of the Top Hard Coal, extending from Bobbers Mill in a westerly direction towards Bilborough Church, and considered to be about 300 yds. in width.

In the Radford Colliery to the south, the shafts entered the Coal-measures directly beneath the alluvium, reaching the Top Hard at a depth

[1] J. Shipman, 'The Coal-measures of the Leen Valley.' *Trans. Notts. Nat. Soc.*, for 1894.

	Character.	Subdivision.	Thickness in feet.	Shaft or Boring.	Characteristic Fossils.
The Red-and-Grey Series.	Red Sandstones and Marls	Keele Group	188	Thurgarton	
	Grey Sandstones, Shales, and Thin Coals	Newcastle-under-Lyme Group.	53	Thurgarton	*Pecopteris arborescens.*
	Red Marls and Green Grits	Etruria Marl Group	283	Thurgarton, Oxton	
The Grey Chief Coal-bearing Series.	Shales and Sandstones	Middle Coal-Measures of Yorkshire	475	Bestwood, Oxton	*Anthracomya phillipsi* in upper part. Marine band, with *Nucula*, etc. above Clowne Coal.
	Clowne Coal		—	Bestwood	
	Shales and Sandstones		615		
	Top Hard Coal		—	Bestwood, Oxton, Owthorpe (?)	
	Shales and Sandstones with Dunsil and Waterloo Coals		496		Marine band 300 ft. above the Deep Hard at Morton Colliery.
	Deep Soft Coal		—	Radford, Clifton, Edwalton, Owthorpe (?)	
	Shales and Sandstones		42		
	Deep Hard Coal		—	Radford, Clifton, Edwalton, Owthorpe (?)	
	Shales and Sandstones with Piper, Hospital and Furnace Coals		334		*Carbonicola robusta.*
	Blackshale or Silkstone Coal		—	Edwalton, Owthorpe (?)	
	Shales and Sandstones	Lower Coal-measures of Yorkshire	500	(Estimated)	
	Kilburn Coal		—		
	Shales and Sandstones		46		
	Wingfield Flagstones		226	Ruddington (in part)	
	Shales		144		
	Naughton Coal		—	Ruddington	
	Shales and Sandstones		129		Marine band forms roof of Alton Coal.
	Alton Coal		—	Ruddington	
	Shales		58		Marine fossils.
	Millstone Grit Series at Ruddington				Marine fossils.

of 240 ft. from the surface. The pits were sunk to the Deep Hard Coal, which is here of a somewhat unusual character, containing a thin parting of sandstone, from 3 to 18 ins. in thickness.

Clifton Colliery.—At a short distance S. of Radford Colliery the Coal-measures become concealed beneath the Trias. Between the shafts of the Newcastle Colliery and those of Radford the Coal-measures rise steadily to the south. That the rise continues in this direction is proved by the shafts of the Clifton Colliery, situated on the northern banks of the Trent, 1½ miles S.E. of Radford Colliery.

The shafts at Clifton Colliery, sunk after several preliminary borings, reached the Top Hard at 53 ft. beneath the Trias, which is here 157 ft. thick. While, therefore, the Triassic rocks sink to the south, the Coal-measures slope upward in this direction.

The sequence of the strata and the depths to the seams are diagrammatically shown in Plate I. There is no record of the occurrence of fossils at about the horizon of the marine band at Morton above the Deep Soft Coal; but Shipman (*op. cit.*) records the presence of teeth, scales, and vertebræ of *Megalichthys* and spines of *Ctenacanthus* and *Gyracanthus* in the roof shales of the Deep Soft and Deep Hard Coals.

The seams worked at Clifton are the Deep Soft and Deep Hard coals. Both show an appreciable thickening when compared with the same seams at Radford. The Top Hard Coal is also thicker than at Radford, though it is not worked, owing to its proximity to the water-bearing Triassic rocks.

Bestwood Colliery.—The sinking of the shafts of this colliery was the first attempt made to reach the Top Hard Coal under the Trias at any considerable distance from known workings. The success attending this undertaking, which at the time must have been considered a bold speculation, has led to the opening up of several collieries along a line extending from Gedling to Doncaster. At first the fresh explorations were carried northward; they are now slowly but surely creeping eastward.

The Top Hard Coal was reached at Bestwood at a depth of 1,244 ft. The depth at which the seam was attained proves, in the absence of any known faulting, that the dip of the measures flattens to the east, for if the dip of 5 degrees at the outcrop had continued, the depth to the Top Hard at Bestwood would have exceeded 2,000 ft.

In the shafts, the Top Hard is 6 ft. 8 in. thick, but gradually decreases in thickness when followed to the east. The inclination slowly diminishes in the same direction. The Top Hard Coal is the only seam raised; though the Gedling Colliery has proved that one, at any rate, of the higher seams is workable there.

In the record of the sinking there is no mention of any fossiliferous bands, though the two marine horizons must be represented, for they have been found in all the recent sinkings and borings to the east and north.

Gedling Colliery.—The success attending Bestwood Colliery and the proof obtained that the dip of the measures gradually decreased to S.E. and E. led to a boring being put down near Gedling. This experimental trial was considered to have reached the Top Hard at a depth of 1,372 ft. Two shafts were subsequently sunk near the site of the boring, and by the courtesy of the owners we were permitted to examine the material from time to time during the progress of the sinking. The shafts, situated 3 miles N.E. of Nottingham, commence in the Keuper Waterstones. The basal breccia of the Permian formation was penetrated at a depth of 508 ft. 2 in., this breccia being 8 in. thick. Beneath this, about 20 ft. of strata described as "red rock" were passed through. The shafts were then continued in red and mottled marls to a depth from the surface of 637 ft., below which they were carried down through ordinary grey and black Coal-measures with seams of coal, and finally it was considered that the Top Hard Coal was reached at a depth of 1,374 ft,

Respecting the first 20 ft. of "red rock" we are unable to give any opinion, as the material had been covered up before our visit; but the underlying red and mottled marls (107 ft. thick) undoubtedly belong to the Etruria Marl Group. Judging from experience gained in the other coalfields of the Midlands, the grey Coal-measures immediately below these marls should belong to a horizon high up in the Grey chief coal-

bearing Series. The upper portion of this Series in the coalfields to the west of the Pennine Chain is characterised by the presence of *Anthracomya phillipsi*, and Messrs. Culpin and Grace have recently found this to be the case also at Conisboro' in Yorkshire. This fossil was found at Gedling to be fairly abundant throughout the first 190 ft. of strata beneath the Etruria Marls, so that the succession falls into line with that of the other Midland coalfields.

Between 825 ft. (below which *A. phillipsi* was not found) and the Top Hard Coal several "mussel bands" were met with, the fossils of which were kindly determined for us by Dr. Wheelton Hind (see below). The absence of *Carbonicola robusta* is noteworthy. At 844 ft. a blue shale ("blue clunch" in the sinking record) yielded large forms of *Lingula* and *Orbiculoidea* in association with fish remains, consisting of the scales of *Cœlacanthus*, and, excepting the head portion, a nearly complete specimen of *Acanthodes wardi*. At a depth of 1,022 ft., a similar shale contained *Lingula*. The bottom of this bed was a hard grey argillaceous limestone with *Lingula* and *Productus*. A subsequent examination of the material obtained from the sinkings at the Sherwood, Mansfield, and Manton Collieries leads us to conclude that this fossiliferous bed at Gedling represents the same horizon as the marine bed, much richer in fossils, met with at about 600 ft. above the Top Hard Coal in the above-mentioned collieries, and 528 ft. above the same seam at Oxton. The objection may be raised to this proposed correlation, that only *Lingula* and *Productus* were obtained at Gedling. But it is quite probable that a richer fauna does occur there, which we failed to obtain, owing to the difficulty in gaining access to all the material during our visits, as much of it was necessarily soon hidden. At any rate a similar shale, with the hard grey limestone at the base, containing the distinctive fauna of the Mansfield marine-bed and in a similar position in relation to the Top Hard Coal, was met with recently in the Oxton boring (p. 17).

The fossils obtained at Gedling which are preserved in the Survey collection are given in the following list. The plants have been identified by Mr. R. Kidston, F.R.S., and the Lamellibranchiata by Dr. Wheelton Hind. The numerals indicate the depths from the surface, in feet, at which the specimens were found.

Neuropteris gigantea *Sternb.* [1,195.]
„ obliqua *Brongn.* [1,190.]
„ rarinervis *Bunb.* [1,195.]
Pinnularia sp. [1,190.]
Lepidodendron obovatum *Sternb.* [1,195.]
„ rimosum ? *Sternb.* [1,195.]
Lepidophyllum lanceolatum *L. & H.* [1,190.]
Lepidostrobus variabilis *L. & H.* [1,195.]
„ sp. [884 and 1,195.]
Sigillaria cordiformis *Kidst.* [855.]
„ laevigata *Brongn.* [855.]
Stigmaria ficoides *Sternb.* [Throughout.]

Orbiculoidea nitida (*Phill.*) [844.]
Lingula mytiloides *J. Sow.* [844.]
Anthracomya calcifera ? *Hind.* [825.]
Carbonicola acuta (*J. Sow.*) [1,330.]
„ aquilina (*J. de C. Sow.*) [1,119.]
„ subconstricta (*J. Sow.*)
„ sp.
Naiadites modiolaris (*J. de C. Sow.*) [932.]

Beyrichia arcuata ? (*Bean.*)
Acanthodes sp.
Callopristodus pectinatus (*Ag.*)
Coelacanthus elegans *Newb*
Megalichthys hibberti *Ag.*
„ sp.
Platysomus sp.
Rhizodopsis sauroides (*Will.*)

The seams of coal at present worked at Gedling are the one named the High Hazles and the seam considered to be the Top Hard Coal of Bestwood Colliery. The High Hazles (3 ft. 9 in. thick) is a good house-coal, containing a remarkably small amount of ash. The seam regarded as the Top Hard yields house- and steam-coal; its thickness in the shafts is 2 ft. 9 in., but materially increases as it is followed towards Bestwood to the north-west, and in the direction of Thurgarton to the north-east.

Bestwood and Gedling compared.—We have elsewhere[1] expressed the opinion that the Etruria Marl Group is everywhere comformable to the underlying measures. At Gedling the Etruria Marls are 109 ft. thick, and the base is 735 ft. above the seam called the Top Hard. At Bestwood it is somewhat difficult to say if the Etruria Marls are present. Mention is made in the record of 6 ft. of blue and brown bind at a depth of 232 ft., or 1,006 ft. above the Top Hard Coal. Mr. Aveline states that the Manager, Mr. Howard Allport, told him :—"In sinking the Bestwood pits the first stratum, found a short distance below the Magnesian Limestone, seemed to tally with the red clay or marl from the bottom of the Scarle boring."[2]

Mr. Aveline places the base of the Permian at 144 ft. from the surface, or 1,087 ft. above the Top Hard Coal. The record, however, does not mention any red measures except those at a depth of 232 ft., the strata between 144 ft. and 232 ft. being described as grey in colour. Assuming that the red measures at 232 ft. belong to the Etruria Marls, then at least 1,000 ft. of grey measures lie between the base of the Etruria Marls and the Top Hard at Bestwood, as compared with 735 ft. at Gedling. Does this afford an example of local unconformity, hitherto unrecognised anywhere in the Midlands, of the Etruria Marls to the Grey chief coal-bearing Series; or does it imply a thinning of the measures between Bestwood and Gedling? Or, failing these, can any other explanation be offered to account for the facts?

The problem is one of considerable importance to the mining industry of the neighbourhood, but cannot reach a satisfactory solution until further data are available.

The palæontological succession, as previously stated (p. 14), indicates the conformability of the Etruria Marls to the Grey chief coal-bearing Series at Gedling; and this relationship also holds good at Thurgarton (p. 17) and at Oxton. Stratigraphical evidence for their conformability is likewise forthcoming, for while these red measures are met with in the eastern or deeper parts of the concealed coalfield, they are absent in the west, or towards the general rise. It is true that in the Leen valley Shipman ("Geology of the Parish of Lenton," p. 19) describes some 8 ft. of light green and variegated Coal-measure shales as underlying the Bunter at Radford; and 35 ft. of mottled clays are mentioned as occurring 228 ft. above the Top Hard Coal in a boring at old Radford. The first are without doubt stained Coal-measures, for a similar discoloration can be found at various horizons along the southern outcrop, wherever, indeed, the Trias rests on steeply-inclined Coal-measures. In the second instance the mottled clays may be in part stained Coal-measures and in part Permian. In the Radford Colliery, between 200 and 300 yds. N. of the boring, where both Permian and Trias are absent, the shafts entered grey Coal-measures immediately beneath the alluvium of the Leen Valley.

If an unconformity existed at Gedling, it would, therefore, even on stratigraphical grounds, be peculiarly exceptional and local.

A thinning out of the measures may have taken place between Bestwood and Gedling, but this supposition has at present no definite evidence in its favour, as, excepting the Top Hard Coal, there is as yet no reliable datum in this district by which to compare one colliery-shaft section with another, while to assume that a diminution in thickness takes place by merely

1 'Geology of the North Staffordshire Coalfields' (*Mem. Geol. Surv.*), 1905, p. 55; 'The Characters of the Upper Coal-measures" *Quart. Journ. Geol. Soc.*, vol. lvii, 1901, pp. 252–262.

2 'Geology of the Country around Nottingham' (*Mem. Geol. Surv.*), 2nd ed., 1880, p. 11.

comparing the Gedling and Bestwood sections is begging the question. No fossils are mentioned in the record of the Bestwood sinking, so that the two marine bands found at Gedling unfortunately lend no aid to the comparison of the sections, but it is significant that in the Mansfield and Sherwood Collieries, where two, and only two, marine horizons were recognised above the Top Hard Coal, the lowest occurs at a short distance above the Clowne Coal, just as it does above the "High Hazles" of Gedling.

By taking the coal at 1,374 ft. in depth at Gedling and the Top Hard Coal at 1,241 ft. in depth at Bestwood as a datum line for comparing the two sections, peculiar difficulties are encountered. If, however, the *High Hazles*, of Gedling be placed on a line with the *Clowne Coal* (623 ft. in depth) of Bestwood, these difficulties disappear. On this basis of comparison it is found that the positions of the numerous coal seams in the two sections agree very closely: far more closely, indeed, than if the Top Hard Coal of Gedling is used as a base level. This method of correlation also permits the presence of a few feet of red measures beneath the Permian at Bestwood.

The local opinion that a fault of 52 yds. was passed through in the boring cannot be maintained, for the shafts and colliery workings prove that there is no fault in this position.

Borings.

To the east and south of Nottingham several borings (see Map on Plate I) have been put down to prove the Coal-measures underneath the Trias. The most important are those of Oxton, Thurgarton, Edwalton, Owthorpe and Ruddington, of which the details are given in Appendix I. (pp 100–116).

Thurgarton.—This boring, situated 6 miles N.E. of Gedling Colliery, entered Keuper Marl beneath 21 ft. of alluvium. The total thickness of Trias and Permian proved to be 839 ft. The red sandstones and marls, 188 ft. in thickness, underlying the breccia at the base of the Magnesian Limestone, are of a type unknown elsewhere in the Eastern counties; but similar rocks have a considerable development and wide distribution west of the Pennines, where they have long been known under the name of the "Salopian Permian." It has been demonstrated that the lower 900 ft. of the "Salopian Permian" belong to the Coal-measures,[1] and for these strata the term "Keele Group" has been adopted. Mr. R. Kidston[2] considers the Keele Group to be of the same age as the Radstock beds of the Somersetshire Coalfield, and to constitute the lowest group of the upper Coal-measures. M. de Lapparent, however, places them at the top of the Middle (Westphalian) Coal-measures.[3] That the red sandstones and marls underlying the Magnesian Limestone at Thurgarton belong to the Keele Group is determined by the following fossil plants identified by Mr. R. Kidston and preserved in the Sedgwick Museum, Cambridge:—*Cordaites* sp., *Sphenophyllum* sp., *Neuropteris varinervis* Bunb. *Pecopteris arborescens* (Schloth.), *P. miltoni* (Artis), *Sphenophyllum* sp.

The grey sandstones and shales, 91 ft. thick, which occur beneath the Keele Group at Thurgarton, evidently represent the Newcastle-under-Lyme Group of North Staffordshire, and its equivalents, the Halesowen Sandstones of South Staffordshire, and the Coedyrallt Rocks of Denbighshire; but the thickness, unless a fault was passed through, is much below that of their representatives in the other areas. The following plants from these beds, identified by Mr. R. Kidston, are in the Sedgwick Museum, Cambridge:—*Alethopteris aquilina* (Schloth.), *Lepidostrobus* sp.

The underlying unstratified red and mottled marls with the characteristic

1 T. C. Cantrill, *Quart. Journ. Geol. Soc.* vol. li, 1895, pp. 528—548. W. Gibson, *Quart. Journ. Geol. Soc.*, vol. lvii, pp. 252—262, also 'Geology of the North Staffordshire Coalfields' (*Mem. Geol. Surv.*), 1905, pp. 53–55.

2 *Quart. Journ. Geol. Soc.*, vol. lxi, 1905, p. 320.

3 Traité de Géologie, 1895, p. 926.

bands of green grits (Espley Rocks) can be unhesitatingly referred to the Etruria Marl Group of the other Midland coalfields. The base of the Etruria Marls at Thurgarton, as elsewhere, is not clearly defined, but cannot be drawn at a higher horizon than the mottled marl at a depth of 1,374 ft. This gives a thickness of 865 ft., of grey ordinary Coal-measures between the base of the Etruria Marls and the bottom of the boring (2,239 ft. 6 in.). At Gedling, if the correlation now suggested (p. 16) be correct, a little over 1,000 ft. of grey measures lie between the base of the Etruria Marls and what upon this supposition should be the actual horizon of the Top Hard Coal; at Bestwood 1,009 ft. at least, and at Oxton 1,170 ft. of grey measures separate the same horizons. If this evidence can be trusted, it would therefore appear that the probable position of the Top Hard Coal was not reached at Thurgarton.

Oxton.—Situated a little over 7 miles W.N.W. of the Thurgarton boring and 3 miles N.W. of that of Woodborough, this boring, completed in April, 1907, affords important information about the unproved coalfield lying to the east of the present limit of workings in the Linby and Newstead collieries.

The boring commenced in the Bunter; and at 374 ft. 6 in. from the surface the Red Marls of the Permian were entered. The total thickness of Permian is 141 ft. 6 in., thus showing a considerable increase as compared with Bestwood, Gedling, and Thurgarton. This increase, it will be noted, is mainly due to the thickening of the 'Marl slates.' The breccia at the base is made up of angular fragments of several rocks set in a coarse matrix containing pockets of arsenical pyrites.

The Coal-measures beneath the breccia consist of 110 ft. of red and purple mottled clays of the characteristic Etruria Marl type, containing thin bands of greenish sandstones comparable with the Espley rocks of Thurgarton. The "hard blue-grey stone" at 584 ft. is a fine-grained, slightly calcareous sandstone bearing a close resemblance to the siliceous varieties of the *Spirorbis*-limestones of the Upper Coal-measures, but in the Oxton specimen no organisms could be detected under a hand lens. As at Gedling, the group does not possess a clearly-defined base, but, by the intercalation of grey with red measures, passes down into the ordinary grey strata of the Grey chief coal-bearing Series.

Taking the base of the Etruria Marls to occur at a depth of 743 ft., the thickness of Grey measures above the Top Hard Coal, which was reached at a depth of 2,026 ft., amounts to 1,283 ft. At Annersley Colliery, where the shafts enter the Coal-measures below the Etruria Marls, the Grey measures above the Top Hard attain a thickness of 1,218 ft. Therefore no appreciable diminution in the thickness of these beds takes place between Annersley and Oxton.

The productive measures, as will be seen from the record given in Appendix I., p. 109, belong to the usual Nottingham type, allowance being made for the difficulty of ascertaining by drilling the exact thickness of thin coals. The band of shale with marine fossils between 1,473 ft. and 1,498 ft. 6 in. in depth, or 528 ft. above the Top Hard Coal, is undoubtedly on the same horizon as the one 625 ft. above the same seam at Mansfield Colliery (Crown Farm), 6 miles N.W. of Oxton. At each locality the basal bed is a hard dark-blue argillaceous limestone containing *Productus*, *Lingula*, *Pterinopecten*, and goniatites. The fossiliferous shales are of the same blue fine-grained character as at Mansfield, having a soapy feel to the touch and containing the same fucoid-like markings. Their fossils include *Lingula mytiloides*, *Pterinopecten*, *Posidoniella sulcata*, and goniatites.

Wilford Boring.—This was a preliminary boring put down on the S. bank of the Trent, near Wilford village. It proved the Top Hard Coal at a depth of 498 ft., or 288 ft. deeper than the depth at which this coal was subsequently found on sinking the shaft of the Clifton Colliery. This discrepancy is due to a fault of 285 ft., which the colliery workings have proved to intervene between the two shafts. The boring proved:—Alluvium 21 ft.; Keuper 192 ft.; Bunter 246 ft.; and Coal-measures down to the Top Hard Coal, 39 ft.

Highfield Boring, Beeston.—This is situated close to the Midland Railway, 1½ miles W.S.W. of Clifton Colliery. The Coal-measures were reached under a cover of 22 ft. of Alluvium and 230 ft. of Bunter. The highest measures are considered by Mr. G. Elmsley Coke [1] to lie 208 ft. below the Top Hard Coal. It is considered that the Deep Soft Coal, 3 ft. 10 in. thick, was found at 559 ft., and the Deep Hard Coal, 6 ft. thick, at 606 ft. below the surface.

Spinney Boring.—This boring, the first attempt to prove the Coal-measures south of the Trent, was made at a spot situated 1½ miles nearly due S. of Clifton Colliery. The Coal-measures were found at a depth of 513 ft. beneath the surface. The identification of a seam, 6 ft. 3 in. thick, at a depth of 558 ft., as the Top Hard Coal has however been challenged ; (see Coke, *op. cit.*).

Edwalton.—This boring lies 2¾ miles S.E. of Clifton Colliery. It is considered by Mr. G. E. Coke (*op. cit.*) to have entered the Coal-measures at a horizon a short distance above the Dunsil Coal and to have ended at the horizon of the Black Shale or Silkstone Coal. If this be the case, the marine band above the Deep Soft Coal should have been passed through ; but the record makes no mention of fossils anywhere near this horizon. "Shells," without further particulars, are mentioned as occurring above the Furnace Coal : in the Derbyshire Coalfield, *Carbonicola robusta* is generally common at this horizon.

Owthorpe.—This experimental boring, situated 6 miles E. of Ruddington, 7 miles S.E. of Clifton Colliery, and 4 miles S.E. of Edwalton, was commenced in the year 1875.

The record down to a depth of 1,313 ft. was published in the Survey Memoir on "The Geology of South-West Lincolnshire" (p. 150), but the thicknesses there ascribed to the Lias and to the subdivisions of the Trias differ from those of the authenticated section now given in Appendix I. (p. 100).

The Secondary rocks in which the boring commenced, and about the first 200 ft. of the Coal-measures, were drilled on the flat-rope system, and samples of the cores only have been preserved ; but the cores obtained by the diamond drill have been carefully kept.

The Coal-measures were entered at a depth of 1,069 ft., the first 15 ft. consisting of red shales and red sandy shales, but owing to the absence of sufficient data it is impossible to give the exact horizon to which these red strata belong. The determination chiefly rests on the position to be assigned to a marine band, about 30 ft. in thickness, commencing at a depth of 1,572 ft., and containing abundant remains of *Pterinopecten papyraceus*, *Lingula mytiloides*, goniatites, and one specimen of a gasteropod. With the exception of the gasteropod, this fauna is common to three of the four marine bands which, as previously stated (p. 11), occur in the Grey chief coal-bearing Series. The lithological character of the strata above and below preclude this marine band being the one above the Alton Coal ; but while the character of the shales and ironstones containing the fossils closely resembles the bed 300 ft. above the Deep Hard Coal, the gasteropod is so far known to occur only in the bed above the Clowne Coal, which lies several hundred feet above the Top Hard Coal in the Mansfield district. Conclusions as to horizon, based on the occurrence of one species of gasteropod, cannot, however, be said to possess much value.

Unfortunately little help is afforded by the fossils above and below the marine horizon at Owthorpe. The fossils consist of *Carbonicola aquilina*, *Naiadites modiolaris*, and of *Anthracomya senex*, a somewhat rare form, but, like the others, having a wide vertical distribution in the Coal-measures.

The evidence, therefore, as to the exact horizon of the red Coal-measure strata at Owthorpe is uncertain. The marine horizon is either the one 300 ft. above the Deep Hard Coal, or is the one above the Clowne Coal. In the latter case the red measures may belong to the Etruria Marls ; but in either case the horizon of the Top Hard Coal is present.

[1] *Trans. Fed. Inst. Min. Eng.*, vol. xi, 1895-96, p. 339.

Since the Coal-measures, so far as can be judged from the cores, lie in a horizontal position, or nearly so, an extension of the Nottinghamshire Coalfield to the south and south-east of Owthorpe receives considerable support from the results obtained by this boring.

The following notes on the igneous rock met with between 1,943 ft. and 1,985 ft. are supplied by our colleague, Mr. H. H. Thomas :—

"In the hand-specimen the typical rock [E. 6,520],[1] taken from well inside the mass, at a depth of 1,966 ft. from the surface, is grey in colour and moderately coarse in grain ; crystals of augite and felspar are visible to the unaided eye. Towards its upper surface the mass becomes much darker, finer in grain, and more compact [E. 6,518–19]. A specimen taken from about 9 ft. below the upper limit, at 1,953 ft. from the surface, is almost black in colour and evidently rich in iron-ores.

"Under the microscope the coarser rock [E. 6,520] proves to be an ophitic olivine dolerite, composed of augite, olivine, plagioclase-felspars, and accessory iron-ores.

"The augite, which is evidently a highly-titaniferous variety, has a rich plum colour, is pleochroic, and forms ophitic plates, enclosing, and being penetrated by, the felspar-laths.

"Olivine, replaced by calcite pseudomorphs, occurs somewhat sparingly in granules, but a few idiomorphic crystals were noticed.

"The felspars apparently are all basic plagioclase, approximating labradorite ; they are zoned, and occur chiefly as much-twinned narrow laths. The iron-ores originally were almost all ilmenite, but are now converted into leucoxene pseudomorphs.

"There is very little base, and practically no apatite. A few cavities have been filled with radiating masses of calcite having a nucleus of silica.

"The finer-grained rock [E. 6,518–19] presents properties which would without any other evidence lead us to regard it as occurring nearer to the margin of the mass. The minerals are the same as those in the coarser variety described above, but there are certain differences which have a bearing on the origin of the rock. It contains a large amount of glassy base rendered almost opaque by rods and skeleton-crystals of iron-ores. Olivine is more plentiful, and there is an increased prevalence of crystals with good outline. The augite occurs in smaller plates, and there is a marked tendency towards idiomorphism. Small chlorite-lined cavities contain colourless isotropic analcime, while a good deal of chloritic and serpentinous material has been localised in the decomposing felspar.

"From the above characters, especially the apparent segregation of olivine and iron-ores towards the margin of the mass, it would seem that the rock is intrusive in character.

"Compared with the rock met with in the shaft of the Whitwick Colliery,[2] the Owthorpe dolerite presents a general similarity ; there are, however, several features in which it differs. It has a smaller proportion, of olivine, and this mineral at Whitwick is altered to serpentine instead of being replaced by calcite. The Owthorpe rock has a deeper coloured augite, less apatite, more iron ores, and more ilmenite than magnetite."

Ruddington.—This boring, commenced in the year 1895, is situated about 3 miles due S. of Clifton Colliery. There can be no doubt that it proved a Carboniferous sequence from about the lower half of the Wingfield Sandstones down to 109 ft. in the Third Grit (Kinderscout Grit), as the strata agree closely both in lithological character and sequence with those found at this horizon by Mr. Wedd in the Derbyshire and North Staffordshire coalfields.[3] It is, therefore, evident either that the measures between Clifton Colliery and the bore-hole rise somewhat rapidly to the south, or that a fault intervenes between Clifton and Ruddington. In either case the boring suffices to indicate the south-western boundary of the coalfield. The evidence is so clear that it was indeed hardly necessary to have con-

[1] Number of rock-specimen in Survey Collection.

[2] 'Geology of Leicestershire and S. Derbyshire Coalfield' (*Mem. Geol. Surv.*) 1907, p. 35.

[3] 'The Geology of the Southern Part of the Derbyshire and Nottinghamshire Coalfield' (*Mem. Geol. Surv.*), 1908, pp. 72-74.

tinued the boring below the First Grit, as this rock is quite distinct in character from any Coal-measure sandstone. It is to be regretted that search was not made for the marine fossils that occur above the Alton Coal, as these are distinctive enough to have proved the horizon reached at 1,072 ft. in depth.[1]

Comparing the section revealed between the base of the Wingfield Sandstone (797 ft. in depth) and the top of the First Grit (1,131 ft. in depth) with that recently proved by the new sinking at Denby Colliery (*op. cit.*), where these measures are 383 feet thick, it will be seen that the south-easterly diminution in the thickness of the strata amounts to only 46 ft. in a distance of 14 miles.

The Millstone Grits from the top of the First Grit to that of the Third Grit are about 100 ft. thicker than in the Derwent Valley between Ambergate and Belper.

In Shipman's MS. notes [2], it is mentioned that the following fossils were obtained from the Ruddington cores:—*Acanthodes wardi*; *Carbonicola acuta*; *C. acuta* var. *rhomboidalis*; *C. aquilina*; *Anthracomya modiolaris*; and *Lingula*.

Structure Revealed by Underground Workings and Borings.

The colliery workings in the Leen Valley show that the general easterly or north-easterly dip of 5 deg. observable in the Coal-measures at their outcrop decreases eastward and south-eastward to between 1 and 2 deg. At the Bulwell Pits (Sheet 125), a little to the west of the Leen Valley, the inclination is 1 in 18, or a little over 3 deg. to the north-east. At Bestwood Colliery 330 yds. N.E. in the direction of full dip, the Top Hard Coal has an inclination of 1 in 37, or a little under 2 deg. At Gedling the dip is again under 2 degrees. How far to the east of Gedling and Bestwood the inclination continues to diminish is not known, but the presence of the upper Coal-measures (Keele Group) at Thurgarton may indicate that up to this point, at any rate, the measures must continue to dip to the north-east, unless, indeed, these higher strata are introduced by faulting.

In following the workings in the coal-seams of the Leen Valley in a southerly direction towards Clifton Colliery, a steady rise to the south takes place. The workings in the Deep Soft and Deep Hard Coals at Clifton Colliery also show that a slight but appreciable southerly rise continues to the limit of the present workings near Wilwell Farm. To the south of this point either the strata must bend up somewhat sharply, or a fault with a downthrow to the north must come in to account for the Kilburn Coal having cropped out before the Ruddington boring is reached. Between Ruddington and Edwalton the inclination must be towards the north-east, in order to bring in the Dunsil Coal at Edwalton.

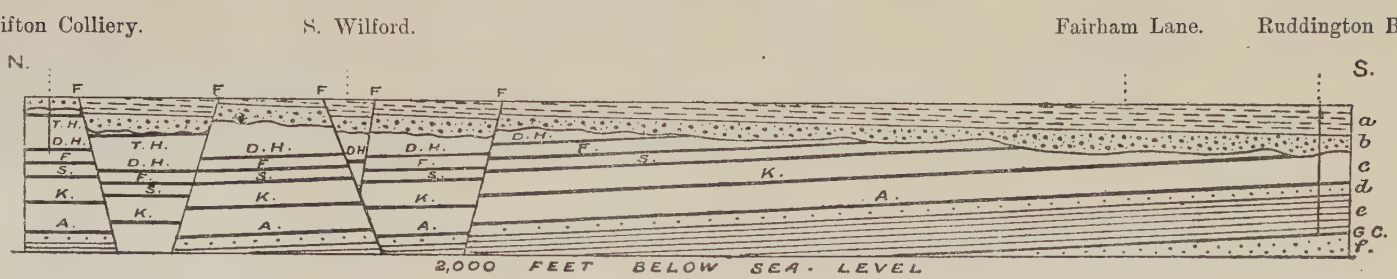
The opinion expressed in 1871 by Professor Ramsay, Mr. Green, and others, that the coal-bearing strata of the Nottinghamshire Coalfield lay in a basin has therefore been confirmed by the underground explorations undertaken since that date.

[1] Since this was written, we are informed by Mr. R. D. Vernon that he has found *Pterinopecten* in the roof-shale of this coal in cores from Ruddington in the possession of Mr. G. Elmsley Coke at Nottingham.

[2] MSS. in the University College, Nottingham.

Fig. 2.—Diagrammatic Section from Clifton Colliery to Ruddington Boring.

Scale (Horizontal and Vertical): 2 in. to the Mile.



a. Keuper Marl.
b. Bunter Sandstone.
c. Coal-measures.
d. First Millstone Grit.
e. Millstone Grit Shales.
f Third Millstone Grit.

T.H. Top Hard Coal.
D.H. Deep Hard Coal.
F. Furnace or Tupton Coal.
S. Silkstone or Black Shale Coal.
K. Kilburn Coal.
A. Alton Coal.
G.C. Grit Coal.
F Faults.

Faults.

Towards the deeper portions of the syncline, the workings of Bestwood and Gedling collieries show a remarkable absence of faulting, but on approaching the southern margin of the concealed coalfield numerous faults, some with considerable downthrows, come in. These faults appertain to two systems, one having a general east-and-west direction, and the other trending nearly north-and-south. Direct proof of the relative ages of these two systems is wanting, but from the known structure in other areas, and from a study of the faulting in the exposed coalfield, one is led to suspect that both systems were initiated during the folding of the Carboniferous rocks. Some of the faulting was completed before the deposition of the Permian rocks, but movement along the same lines was continued long after the Keuper Marl was laid down. The post-Triassic disturbances were, however, of most irregular intensity. Thus the E.—W. fault of 261 ft. vertical displacement in the Coal-measures at Cinderhill has only a trifling effect on the overlying Permian. On the other hand, the E.—W. fault, with a throw of 285 ft. in the Coal-measures at Clifton Colliery, displaces the overlying Triassic rocks nearly to the same extent.

When these faults are followed westward they are found to turn to the north and ultimately assume a nearly N.—S. direction in the exposed coalfield. The faults thus change their orientation in agreement with the change of strike due to folding. Traced in the opposite direction, eastward, the Cinderhill Fault shows a distinct tendency to bend to the south, but the 285 ft. Clifton Fault has not been followed far enough to the east to prove what line it takes. Other faults, however, proved in the workings at Clifton Colliery show a slight northerly deviation.

Few of the faults proved underground can be traced at the surface. The above-mentioned Clifton (285 ft.) Fault is, however, clearly seen in Cut Through Lane, E. of Lenton Hall, where it brings Keuper Marl against the lower portion of the Bunter Pebble Beds. A little farther E., in the river bluff N. of Tottle Brook, Keuper Waterstones have been brought in touch with the Lower Mottled Sandstone of the Bunter. The fault may, therefore, be estimated to possess a throw of between 240 to 270 ft. in the Trias, but allowance should be made for the probable overlap of the Keuper. In the bed of the Trent[1] 400 yds. S.W. of Trent Bridge, red Keuper marls with skerries on the south are in contact with the Bunter Pebble Beds on the north (see p. 81). If this is the surface position of the Clifton Fault, the hade in the Trias must be very much lower than in the Coal-measures at Clifton Colliery. The complex system of faulting proved in the Coal-measures of the Leen valley has apparently little effect on the Permian and Trias. The surface positions of these faults can, therefore, seldom be defined with

[1] Our thanks are due to Mr. F. Rayner, of the Trent Navigation Board, for this and other information respecting the bed of the river

any certainty, and faults other than those shown on the map may, and probably do, occur.

The faults shown in the area occupied by the central and eastern parts of Nottingham City are taken from Mr. Shipman's carefully prepared map. The proof for the existence of many of these faults, and, in many cases, their actual positions, were obtained by Shipman from an almost daily examination of numerous artificial excavations. There is no doubt that most of this information would have been lost but for the patient attention given to the excavations by this careful and indefatigable observer.

These Nottingham faults anastomose in a belt trending north-west and south-east. The most northerly fault is still visible in the cutting of the Great Northern Railway 530 yds. S. of Carlton Road. If the direction of this fault, as shown by the broken lines on the map, be continued to the Trent Valley, it reaches the old river-bluff at a spot where a gypsiferous belt, seen to the east, abruptly makes its appearance. Traced to the east, the gypsiferous bands terminate against a second fault, clearly seen in the steep cliff-face. This fault has a hade of 40 deg. to the north-east.

Another fault belonging to this belt was visible at the time of the re-survey on the east side of Mansfield Road, 300 yds. S. of Carrington Station, but is now being rapidly concealed. It brings Keuper Waterstones against Bunter.

Underground Extension of the Coalfield.

The whole of the eastern area included in Sheet 126, and of that represented on the small scale map (Plate I.), falls within the limit of the concealed coalfield as defined by the Royal Commission on Coal Supplies in 1902. For the purposes of the present map, it is unnecessary to discuss the wider extension formulated by Professor P. F. Kendall, who, from a careful consideration of all the available geological data having a bearing on the subject, considers that this concealed coalfield may extend in a south-easterly direction beyond the area now under consideration to the borders of the Fen country.

In 1871 the Commissioners fixed the supposed limit at a line drawn from Ruddington to Newark, a limitation which left the south-eastern portion of Sheet 126 outside the productive zone. This line was based on the interpretation of a boring at South Scarle, 8 miles north-east of Newark, by which certain red marls immediately underlying the Permian at this place were considered by some authorities[1] to be of Lower Carboniferous age. This identification, however, was not acquiesced in by local mining engineers, who thought it more probable that the red marls belonged to the Upper Coal-measures (p. 15). Into the merits of this case it is not necessary for us here to enter, since the later borings at Thurgarton, Edwalton (p. 100), and Owthorpe

[1] 'Geology of the Country around Nottingham' (*Mem. Geol. Surv.*) ed. 2, 1880, p. 11; see also E. Wilson, *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, pp. 812–13.

(p. 106) have justified the extension of the concealed coalfield well to the eastward and south-eastward of the area here dealt with.

The inquiry, therefore, so far as the present map is concerned, resolves itself into a consideration of the accessibility and productiveness of the concealed Coal-measures.

The accessibility of the productive measures depends upon the thickness of the cover of Secondary rocks, and on the presence or absence of the barren measures of the Red-and-grey Series.

The following table of the thickness of the Secondary rocks, as proved in a number of explorations arranged in a general north-east to south-west direction, shows a decided and gradual decrease in thickness of the individual members from north-east to south-west.

TABLE SHOWING THE THICKNESS OF THE SECONDARY ROCKS BETWEEN SCARLE AND RUDDINGTON.

	Scarle, 35 ft. O.D	Thurgarton,[1] 50 ft. O.D.	Gedling,[1] 200 ft. O.D.	Edwalton,[1] 100 ft. O.D.	Owthorpe, 200 ft. O.D.	Ruddington,[1] 120 ft. O.D.
	ft.	ft.	ft.	ft.	ft.	ft.
Lias and Rhætic -	44	—	—	—	47	—
Keuper - -	893	263	76	449	748	466
Bunter - -	541	494	385	255	274	221
Permian	519	93	47	nil	nil	nil
TOTAL	1,997	850	508	704	1,069	687

To the south of Thurgarton, therefore, the increase of cover due to the general inclination of the Secondary rocks introducing higher and higher members is in part counteracted by the decrease in their thickness. To the north-east, however, not only does the dip bring in higher sub-divisions, but there is also a marked increase in their thickness.

The factor of prime consequence in estimating the probable thickness of the superincumbent barren measures is the position of the axis of the buried syncline of the Coal-measures.

Professor Kendall,[2] considering that the red marls at Scarle belong to the Upper Coal-measures, places the axis in close proximity to the site of this boring. As it is, however, altogether uncertain whether the red marls in question belong to the Keele Group or to the Etruria Marls, or, indeed, whether they are Upper Coal-measures at all, we have still no ground on which to determine with certainty whether the measures rise, or fall between Thurgarton and Scarle. The great increase in the thickness of upper measures at Thurgarton as compared with

[1] These borings commenced below the top of the Trias, and do not therefore give the total thickness of the Keuper.

[2] Final Report of the Royal Commission on Coal Supplies, 1905, part ix, pl. 8, fig. 5.

Gedling indicates a north-easterly inclination of these measures up to this point; but whether to the due east of Thurgarton the Coal-measure strata commence to rise, remain horizontal, or continue their general easterly dip is still unknown. Therefore no definite calculation is possible as to the depth to the productive measure in the north-east portion of the map, nor can the axis of the syncline be safely located.

To the south and south-west of Thurgarton the conditions are different, for here the borings at Edwalton and Owthorpe demonstrate a buried coalfield of great potentiality. Though neither of these borings throws light on the position of the axis of the syncline, they do clearly demonstrate a distinct south-westerly rise in the Coal-measures, sufficient to bring about the outcrop of the Middle Coal-measures beneath the Trias at Edwalton and Owthorpe, and the Wingfield Sandstones beneath the same formation at Ruddington.

The question as to the productiveness of the measures has next to be considered. A local opinion exists that the thickness and number of the seams decrease eastwards. This opinion is based mainly upon the recognition of a general but gradual decrease in the thickness of the Top Hard Coal as it is followed to the east, and partly upon the deterioration of some of the lower seams in the Leen Valley, and the apparent barrenness of the measures at Thurgarton.

To what extent or how far eastward the deterioration continues is uncertain. The explorations at Clifton Colliery show that south of the Trent the seams have regained their normal thickness. The workings of Gedling Colliery also prove a gradual increase, rather than decrease, in the thickness of the seams in the direction of Thurgarton.

Considering the local variations in the character and thickness of the seams in the Yorkshire and Derbyshire coalfields, the arguments brought forward for a general absence of seams to the east hardly warrant the condemnation of an area so important as the one bordering the navigable portion of the Trent in the present map.

CHAPTER III

PERMIAN [1]

GENERAL ACCOUNT

Although the area occupied by this formation in the district is very limited, the rocks are of peculiar interest, inasmuch as they represent the southern termination of the great belt of Permian strata which stretches southward from the Tyne. On this account these strata have attracted much attention and have been frequently discussed (see Bibliography, Appendix II., p. 118).

The persistent thinning of the formation as a whole in a southerly direction has reduced the deposits in the present area to a total thickness of not more than 50 ft. This attenuation, along with other features which the deposits present, affords indications that we are here approaching the original limits of the Permian Sea. In Yorkshire an upper and a lower division of the Magnesian Limestone are present, with an intervening group of marls known as the Middle Marls. But in the Nottingham district the sequence is reduced to two members, viz.: (2) Marls, overlying (1) Limestones, with basement breccia in places; and it is generally considered that these two divisions represent the Lower Limestone and the Middle Marls of Yorkshire.[2] This correlation can however hardly be regarded as firmly established, and requires further investigation in the country to the northward, where the Upper Limestone sets in.

The Permian of the present map strikes nearly north and south, parallel to the Bunter, the boundary between them being approximately coincident with the course of the River Leen. The lower boundary of the Permian, which lies mainly within the adjacent map (Sheet 125), is well defined on account of its unconformability to the underlying Coal-measures; but the upper limits of the formation are very indefinite, as the marl appears to pass upward gradually into the Bunter by the intercalation of sandy material, and there is no surface-feature to mark the junction. In fact, in this area it would have been more convenient to regard the marl as the lowermost portion of the Bunter, though its separate indication, as shown on the map, has advantages from the economic point of view, as the marl is of commercial value for brickmaking, etc.

The average dip of the Permian is towards E. by S., at about 1 to 2 deg. only.

Fossils, of marine type, occur sparingly in the Magnesian

[1] By R. L. Sherlock.

[2] W. T. Aveline, 'The Magnesian Limestone and New Red Sandstone in the Neighbourhood of Nottingham.' *Geol. Mag.*, dec. 2, vol. iv, 1877.

Limestone, having been found in three localities only in the Nottingham district, all of which lie slightly farther west than the present map extends. One of these places is the Bulwell Quarries, where hollow casts of shells occur in a particular band. A few indeterminable casts were found in the small pit north of the railway to Ilkeston at the southern limit of the formation; and fossils are also reported from Cinderhill. It should be mentioned, in addition, that the late James Shipman obtained the following fossils from the base of the "Marl Slates" at Gedling Colliery boring (determined by Mr. E. T. Newton):—*Pleurophorus costatus* (Brown), *Bakevellia bicarinata* King, *B. antiqua* Muenst, *Pleurophorus* ?, and *Schizodus* sp.

No fossils are known from the Permian Marl in this district

Magnesian Limestone.

DETAILS.

From the shaft sections at the Bestwood and Gedling Collieries (p. 102) it appears that at these places a calcareous sandstone, probably equivalent to the "Marl Slate" of Kimberley, is present below the Magnesian Limestone, but this is never exposed at the surface in the present map.

In Papplewick parish, due W. of "Robin Hood's Stable," an old quarry on the banks of the Leen shows about 12 ft. of Magnesian Limestone. The rock is the uppermost part of the formation and is overlain by the Red Marl. It is a flaggy, ferruginous dolomite with the bedding practically horizontal.

A little farther S., a cutting in the road from Papplewick to Linby, on the W. side of the Leen, shows some 5 ft. of similar rock; and another road-cutting near Warkmill shows limestone dipping at 2 deg. to the N.E.

There is a disused quarry in the limestone behind *Broomhill House*[1] by the side of the Great Northern Railway. Just in front of *Broomhill House* the road from Mansfield to Nottingham has been cut through a small anticline of limestone, apparently a continuation of the low dome of this rock which lies on the E. bank of the Leen close to Westhouse Farm. Another small elongated dome of limestone parallel to that above mentioned forms a similar low rise across the road at Forge Mill; the beds that occur in it show dips of 32 deg. to the N.N.W. and 22 deg. to the S.S.E.

The small tract of limestone represented in Basford Hall Park [Sheet 125] is cut off to the N. and S. by faults, and does not present any clear exposure. South of High Street, Basford, the limestone is brought in again by another fault and extends to Radford, where a narrow tongue of the Coal-measures is exposed at the surface, and the Permian rocks do not reappear south of this place.

An important section was seen by the late E. Wilson[2] at *Bobbers Mill*, where the *Alfreton Road* crosses the Leen, during the excavations for the Leen Valley Sewage Works. He noticed "that in the course of a couple of hundred yards south from the turnpike gate the thinning-out Magnesian Limestone passes from an ordinary granular dolomite through a fine to a coarse brecciated rock."

[1] Throughout the Memoir, the italicising of place-names denotes that the name is one that is not engraved on the 1 in. map, but will be usually found on the 6 in. map. Broomhill House is exactly on the W. edge of the map, about ½ mile S. of Butler's Hill Station.

[2] 'On the Permians of the North-East of England,' etc., *Quart. Journ. Geol. Soc.*, vol. xxxii, p. 533, 1876.

Shipman in a MS. note[1] says :—"On the west side of the railway, where the main road crosses at *Bobbers Mill*, a sewer-cutting to the depth of about 10 ft. showed Permian Magnesian Limestone (about 3 ft.) overlain by drift and gravel. The limestone was in the usual thin beds about 3 in. thick, with some little marl." In another note Mr. Shipman remarks :—"The culvert at *Bobbers Mill* showed a depth of 6 ft. of thin alternations of marl and magnesian limestone up to as far as the first street (*Chapel Street*). Difficult to tell whether to class it with the limestone or the marl."

In the year 1900, Shipman saw, in a new sewer between *Bobbers Mill Road* and *Plantation Side*, an interesting section 26 ft. deep, in which 15 ft. of Lower Mottled Sandstone of a deep red colour, without pebbles, rested on an even surface of Permian, consisting of 18 inches of red and pale greenish marl with a thin bed of Magnesian Limestone below, and then 10½ in. of laminated red and green marl. Below this was 10 ft. of Magnesian Limestone, with a brecciated band, 8 in. thick at 2 ft. from the base of the section (bottom not seen). The limestone was mostly thick bedded, dipping apparently at 2 deg. to 3 deg. towards S.E., and showed no indication of dying out. Mr. Shipman considered that the upper beds of limestone and marl in this section may represent the Permian Marl. There was no marl seen below this.

The most southerly exposure of the Magnesian Limestone is in a small pit ⅓ mile N. of the Midland Railway branch to Ilkeston, just beyond the western margin of the map. The rock is here of the usual type—a yellowish-brown highly-crystalline dolomite, which contains sand grains and minute pebbles ; obscure casts of shells also occur in it.

Red Marl.

The outcrop of the Permian Marl occupies a narrow belt, which is much obscured by the alluvial deposits of the Leen. The best exposures are in the old quarry on the banks of the Leen, W. of "Robin Hood's Stable," in the brook N. of Congel Hill, and in the old brickyard near Cobler's Hill ; but the deposit may be studied to better advantage in the brickyards at Bulwell in Sheet 125 (see *Mem. Geol. Surv.*, "The Southern Part of the Derbyshire and Nottinghamshire Coalfield," p. 109). Participating in the general southward attenuation of the Permian strata, the marl ceases to be traceable as a separate division S. of Basford Hall, though the underlying limestone has been traced for 1¾ mile farther S. From Mr. Shipman's account of the sewer-section at *Plantation Side, Bobbers Mill*, above referred to, it appears, however, that at this spot the marl may be represented by 2½ ft. of red marl with a thin flaggy intercalation of limestone. The apparent intercalation of the marl with the Bunter at its upper boundary has been briefly discussed in the Memoir on Sheet 125 (pp. 115–16), to which the reader is referred for particulars. It is possible, on this account, that marly beds included with the base of the Lower Mottled Sandstone on the N.W. outskirts of Nottingham may be equivalent to the upper part of the marl of the more northerly area.

The Permian strata have been passed through in several colliery shafts and borings, and these sections give the best evidence as to its thickness and variability. From the records of the sections, the following data are compiled (for some further details see Appendix I., p. 98).

Bestwood Colliery ; 30 ft. of Magnesian Limestone and 19 ft. of Red Marl.

Newcastle Colliery, Basford ; 6 in. of Breccia and 13 ft. of Magnesian Limestone.

Gedling Colliery ; 8 in. of Breccia and 46 ft. of Permian appear to have been passed through.

[1] For access to Shipman's very numerous and important MS. notes we are indebted to Prof. J. W. Carr (see Preface).

No Red Marl occurs at Newcastle; and the whole of the Permian at Gedling is described as "strong grey ground," so that the strata here cannot be correlated with the subdivisions of the Permian at its western outcrop.

The Oxton Boring passed through 141½ ft. of Permian strata, consisting of Breccia, 2½ ft.; Marl Slates, 85 ft.; Magnesian Limestone, 45 ft.; and Red Marl, 9 ft.

The Thurgarton Boring showed 93 ft. of Permian strata, consisting of Marl Slates, 24 ft.; Magnesian Limestone, 34 ft.; and Permian Marl, 35 ft.

Clifton Colliery, and the Edwalton and other borings S. and S.E. of Clifton, proved the absence of the Permian in this quarter (see Plate I.)

CHAPTER IV.

TRIAS.[1]

The scheme of subdivision adopted for the Triassic rocks and the extent of the various subdivisions in the area covered by the map have been outlined in Chapter I. (pp. 4–7), and need not here be repeated. We shall now proceed to discuss the sequence in fuller detail.

Bunter.

GENERAL ACCOUNT.

In those parts of England where the Bunter attains its fullest development it has been sub-divided, solely by its lithological characters, into three members; but, in the district now under consideration, only two subdivisions have been recognised—viz. the "Lower Red and Mottled Sandstone" below, and the 'Pebble Beds" above.

It is only to be expected, from the nature of the deposits, that the beds should present great local variability, according to the different conditions prevailing at the same time in different parts of the area of accumulation, so that the subdivisions in one part of the system are not likely to be exactly equivalent to those in another part. It is therefore probable that, although the uppermost of the three divisions—the "Upper Mottled Sandstone"—cannot be separately identified in Nottinghamshire, it may be represented in this district by part of the so-called "Pebble Beds." These beds are themselves of the nature of sandstones in which pebbles are more or less sparsely distributed, and they never attain to the typical condition of masses of coarse pebbles to which they owe their name.

Excepting the recently-discovered plant remains to be subsequently mentioned (p. 42), the Bunter beds of the Nottingham district have not yielded any trace of a contemporaneous fauna or flora, the only fossils found in them being in occasional pebbles derived from older fossiliferous deposits. Mr. Shipman[2] has noted the occurrence of *Glyptocrinus basalis* in a pebble found in *North Sherwood Street*, Nottingham, and of *Strophomena grandis* in one from the *General Cemetery*, Nottingham, and considered these pebbles to be of Caradoc age.

The Lower Mottled Sandstone and the Pebble Beds are com-

[1] By R. L. Sherlock, with contributions by W. B. Wright and G. W. Lamplugh.

[2] 'Fossiliferous Pebbles in the Bunter,' *Midland Naturalist*, 1882, p. 118.

posed of sandrock which though compact is rarely consolidated into a true sandstone, and can almost always be broken up between the fingers. The Lower Mottled Sandstone differs from the Pebble Beds generally in colour, that of the lower division being red whilst that of the upper is usually yellow or buff, though in Sherwood Forest this also is somewhat red.

Another conspicuous difference between them is in the distribution of pebbles. These are rarely absent when the Pebble Beds are sufficiently exposed, and they are well rounded quartzite greatly predominating, whereas in the Lower Mottled Sandstone such pebbles as do occur are small and angular, occurring moreover in strings and bands of characteristically brecciated aspect, quite different in appearance from the gravelly bands in the Pebble Beds.

There is a further difference in the texture of the rocks, the sandrock of the Pebble Beds being sharp and rather coarse-grained, while the Lower Mottled Sandstone is of much finer grain and loamy texture, passing, in fact, almost imperceptibly into the underlying Permian Marl; and the marl-bands, which are comparatively of rare occurrence in the Pebble Beds, are sufficiently abundant in the Lower Mottled Sandstone to give a laminated aspect to the lower portion of that deposit, not unlike that which characterises the Keuper Waterstones.

Current-bedding is particularly prevalent in the Pebble Beds, and this structure near Nottingham usually shows a dip towards the S.E., indicating that the currents of the period flowed mainly from N.W.

Lower Red and Mottled Sandstone.

DETAILS.

This subdivision attains its greatest thickness in the north-western corner of the map, at Newstead Abbey, and thins southwards. The difference in composition between the upper and lower portions of this sandstone has a marked effect on the topography, the lower marly beds forming nearly flat ground which merges into the plain of the Permian, while the more massive upper part rises abruptly into low steep-sided hills, which are often, though not always, capped by Pebble Beds. Thus, in the section at the S. entrance to the Midland Railway Tunnel through the Robin Hood Hills, it is seen that the Lower Mottled Sandstone forms part of the flat and also the slope of the hills. Similarly, at Newstead Abbey, the formation occupies the nearly flat park E. of the lakes and also the slopes of the Black Hills which rise steeply in the woods; and S. of the park the same double feature of plain and hill can be followed to Papplewick.

The mottled appearance, which gives the name to this subdivision, is due to the occurrence in the red sandrock of greenish-yellow patches, of varied shapes but often with a definite outline. This colour-mottling, however, is by no means prevalent in the area under description, being confined to the southern portion of the outcrop, and to a few spots further north, while in the railway cuttings around Bulwell Forest, and in most other sections, a uniform red coloration of the rock prevails.

At Robin Hood's Stable, near Papplewick, the section in an artificial cave shows about 8 ft. of massive red sandrock with some yellow blotches. At this point the hill-feature swings to the east around a deep coombe, running N. past The Barrack Farm, the sides and bottom of which are probably in the Lower Mottled Sandstone. On the flat land of Papplewick Moor the

boundary between the Lower Mottled Sandstone and the Permian Marl is indefinite owing to a thin covering of the superficial deposits. Congel Hill is an outlier of the upper massive beds. South of Bestwood the outcrop of the formation becomes greatly contracted, owing to the thinning of the sandstones, or perhaps to the lateral passage of its upper portion into the Pebble Beds.

At Bulwell Spring a small section in the lowermost part of the beds shows 2 ft. of red marl on 3 ft. of soft, very fine-grained, red sandstone. Better sections at a higher horizon are presented in the Great Northern Leen Valley line, at the commencement of the Bulwell Forest cutting, where 20 ft. of red massive sandrock is exposed, and again in the cutting, 15 ft. deep, where the Great Central and the Great Northern joint branch line to Bestwood passes underneath the Great Central main line in Bulwell Forest. The presence of a few rounded pebbles at the top of the last-mentioned section has been taken as indicating the base of the Pebble Beds.

There are a few other sections of red sandstone, sometimes streaked with partings of red marl, in and around Bulwell, at, or just beyond, the W. boundary of the map, but this ground and that to the southward is much obscured by gravelly superficial deposits and by buildings, so that the boundaries are difficult to trace.

Where the Great Central Railway passes under the road from Basford to Arnold, a section shows coarse, yellow, pebbly sandrock, resting on red sandrock without pebbles and of finer grain. Close to this section the red sandrock is replaced by yellow and coarser sandrock with a few pebbles, and the boundary line between the Lower Mottled Sandstone and the Pebble Beds has therefore been carried through this place. It is then prolonged for a little distance up the Daybrook Valley, as an exposure at Daybrook Works shows thinly-bedded red sandrock, with coarse-grained yellow lenticles and an occasional small pebble.

A sand-pit in the Lower Mottled Sandstone at *Two Mile Houses*,[1] Basford, where the road to Alfreton leaves the map, shows a clear section of about 20 ft. of red, current-bedded, slightly micaceous, mottled sandrock with a few marl partings and destitute of pebbles, except for a few in a fissure into which they have doubtless dropped from above. The dip of the current-bedding is at 14 deg. to S.E. in one bed, while in the lower beds it is at 20 deg. to N.W.

Some excavations at the *Star Brewery*, *Whitbread Street*, New Basford, gave a section of 15 ft. of fine red and yellow sandrock having the general aspect of the Lower Mottled Sandstone, but containing rounded pebbles such as are characteristic of the Pebble Beds. At the bottom of the section, however, the rock was marly and without pebbles.

From *Plimsoll Street* to *Bobbers Mill* red sandrock with greenish-yellow bands is seen in a cliff about 20 ft. high, which borders the Leen Valley; and at *Bobbers Mill* there are old sandpits showing 6 ft. of red sandrock, of medium coarseness, with greenish yellow patches.

During the excavations for the gasholder at Old Radford in 1879-80 the following important section of the Lower Mottled Sandstone, under a capping of superficial deposits, was noticed and described by the late J. Shipman[2]:—

	ft.
Soft sandrock of the usual type - - - - -	10
Hard compact purplish sandrock - - - - -	14
Brecciated conglomerate - - - - -	2 ft. to 8

The basement conglomerate was thickest on the east side of the excavation and rested on a planed off and even surface of Coal-measures. It "was mainly composed of fragments of the underlying greenish and mottled Coal-measure shales, along with rolled quartzite pebbles, and an abundance of sub-angular fragments of felspathic, granitic, and other igneous rocks, most of them being too much decomposed for examination

[1] See footnote on p. 27 *re* place-names in italics.

[2] 'Geology of the Parish of Lenton' in Godfrey's '*History of the Parish and Priory of Lenton*, p. 22, reprint.

under the microscope." Broad ripple-markings were noticed in the sandrock. The outcrop of the Lower Mottled Sandstone was found by Shipman to terminate at 500 yds. N. of the gas works, allowing the Coal-measures to set in under the alluvium.

South of Radford the Leen alluvium is probably underlain by the Lower Mottled Sandstone, which is seen at *Spring Close*, Lenton. Here a sand pit shows 15 ft. of red and mottled sandrock with films of red marl and layers intermediate between sand and marl, beneath a capping of Pleistocene sand and gravel (see p. 70). The loamy character of the sand increases towards the base of the section.

Reference has been made above to the presence of bands of breccia in the Lower Mottled Sandstone. These are best seen at Kimberley Knowl, which lies beyond the map. One lenticle at this place reaches a thickness of 6 ft., but no such thickness is attained in the present area, and the breccia occurs only in the form of strings of small angular pebbles, often arranged along planes of current-bedding. The breccia, as it occurs in the Great Northern Railway cutting at *Hempshill* is described as follows by the late E. Wilson[1] :— "The breccia contains semi-angular green, blue, and purple slates, more or less rounded grits, quartzites, quartz-breccia, and numerous white and discoloured slabs and nodular balls of fossiliferous Carboniferous-Limestone chert." R. L. S.

Pebble Beds.

Along their north-western margin the Pebble Beds present a prominent and deeply indented escarpment overlooking the softer Lower Mottled Sandstone, but this escarpment becomes less definite as it is followed southward to the Trent Valley.

The southward narrowing of the outcrop, to which reference has been previously made, is due partly to their decrease in thickness in this direction and partly to the slightly unconformable overlap of the Keuper resting upon them (see p. 36). The general characters of the series have been described, and we shall now direct attention to their local development.

North of Bestwood, sections are rare and of limited extent, though, from the scantiness of superficial deposits and the slight depth of the soil, the Pebble Beds are almost everywhere close to the surface. This part of the country is a constantly undulating succession of steep rounded hills and deep coombe-like valleys, for the most part dry, having a very light gravelly or sandy soil, of poor quality agriculturally, and therefore much covered by woods and gorse. The tops of the hills are particularly gravelly, and it is to the protective capping afforded by the more pebbly bands that these features are mainly due.

A gravel-pit, 200 yds. S. of the Barrack Farm, Papplewick, near the base of the Pebble Beds, shows 5 ft. of gravel, chiefly of small quartzite pebbles, covered by 1 ft. of coarse, pebbly, bedded sand and 1 ft. of gravelly soil. This material appears to be in place, but it may possibly have been re-arranged in Glacial or later times.

Another section at about the same horizon occurs in an old sand-pit in the Nelson Plantation, Papplewick, showing 7 ft. of red current-bedded sand with some pebbles and a few fragments of green marl. As in the previous section, some of the pebbles have been disturbed by a superficial displacement and are now in a vertical position. Near the top of the pit, a glacially transported slab of andesitic rock measuring 10 in. by 7 in., probably from the Borrowdale Series of the Lake District, was found. Other small sections of similar character are exposed in gravel-pits ½-mile N.W. of Calverton Lodge and in Gorse Covert, Oxton.

In the road and adjoining gorse-land, due W. of Moorfield, Oxton, a discontinuous section of about 50 ft. of red and brown current-bedded sandstone, with many pebbles, can be made out.

The ground between the Dover Beck and the Keuper escarpment, from Oxton to Moorfield, forms a gravelly plateau dipping at about 1 deg. to S.E., and it probably represents the outcrop and dip-slope of the pebbly

[1] *Quart. Journ. Geol. Soc.*, vol. xxxii, p. 533 (1876).

band exposed in some of the above-mentioned sections. This band lies not far below the top of the Pebble Beds. It is noteworthy that the soil along this outcrop contains numerous pebbles of white quartz.

In Bestwood Warren a large pit has been excavated for moulding sand in the lower part of the Pebble Beds. On the E. side the details of the section are :—

	ft.	in.
Pale buff, coarse, semi-coherent sandrock, with flaggy bedding in upper part, massive below	10	0
Coarse buff sandrock	1	0
Reddish sandrock	1	6
Massive brownish sandrock	3	0

On the S.W. side the section is increased to about 30 ft. of coarse, massive buff sandrock. Pebbles are fairly numerous throughout, and there are small lenticles of red and mottled marl, known to the workmen as 'Fuller's Earth.' The Watch Tower in the plantation stands on a current-bedded compact sandrock, which belongs to a higher horizon of the Pebble Beds. A gravel-pit in the woods, 900 yds. N.E. of the Tower, shows 1 to 2 ft. of gravelly downwash on 10 ft. of stratified white and yellow sand with bands of more compact red sandrock.

In and about the village of Arnold there are numerous small sections of Pebble Beds which do not require particular description; and a few exposures close to the Keuper boundary show that the Pebble Beds maintain their typical characters at this horizon. About 600 yds. to the E. of Daybrook Station the Great Northern line runs through a cutting of 20 ft. in Pebble Beds, with cross-bedding dipping at about 22 deg. to E. Close to the crossing of the roads between Redhill and Daybrook, a new road-cutting showed 6 ft. of yellow sand under 2 ft. of sandy, pebbly soil. The sandrock was free from pebbles, and contained brown bands at intervals of about 3 in., giving an appearance of bedding.

The Great Central main line, running through Bulwell Forest, gives sections which, for the most part, are still in good condition. The cutting in the Great Northern and Great Central joint line at Forest Side has been already mentioned (p. 32), and another cutting, on the "up" line of the same railway, which runs parallel to the G.C. main line, shows the following succession, and marks the downward passage of the Pebble Beds into the Lower Mottled Sandstone.

	ft.	in.
Grassy slope	10	0
Coarse sandrock	9	0
Red marl	0	6
Coarse sandrock	3	0
Red marl	0	6
Sandrock	1	0

Other sections on the G.C. line between this place and Nottingham reveal Pebble Beds of the usual character, with the downward passage into the Lower Mottled Sandstone visible in a few places, *e.g.*, opposite the Sanatorium at Basford. Mr. C. Fox-Strangways, who examined the line at the time of its construction, notes that the tunnels are all in sandrock.

In *Edwards Lane* on both sides of the Daybrook Valley, in the road past Bagthorpe Prison, and in *Hucknall Road*, N. of Bagthorpe Waterworks, there are deep road-cuttings in Pebble Beds. At the last-named place the upper part of the rock is laminated, apparently from weathering, and the yellow rock becomes red. Close by, at *Bagthorpe Farm*, there is another section, 12 ft. deep, of laminated rock. There are a number of small exposures near the Keuper boundary on the east side of *Mansfield Road*. One of these is beside the high road south of the Day Brook, and another is in the new road by the Black Swan Inn. Further S. at the back of *Lloyd Street* and in *Spondon Street* the Pebble Beds are seen within a few yards of the Keuper. The Pebble Beds were exposed in Mapperley Park in a new drain running from *Mansfield Road* towards *Alexandra Park*, and in cross drains. The actual junction with the Keuper is here cut through, but is not clear owing to staining and downwash. Near *Forest House*,

opposite the *Recreation Ground*, there are some crags of Pebble Beds, which have been dug out into caverns. Here a fault throwing down the Keuper could be clearly seen, though the houses now being built will probably entirely conceal it.

Between the Forest Recreation Ground and the Church Cemetery there is an old quarry some 30 ft. deep, in Pebble Beds, and in the Cemetery itself caverns have been hollowed out in the yellow sandrock. The greater part of Nottingham is built on Pebble Beds and the rock not uncommonly crops out in the streets, *e.g.*, at the *Bluecoat School* and *Wollaton Street*. Exposures are especially numerous in the district known as *The Park*, and there is a striking one in *Tunnel Road* which is cut in solid rock under *Park Terrace*.

Coming now to the southern termination of the Bunter, we find a sharp bluff of Pebble Beds along the N. side of the Trent Valley, at the foot of which runs *Lenton Boulevard*. This bluff becomes in places an almost vertical cliff into which artificial caverns have been hollowed out, and it culminates suddenly in Nottingham Castle Crag, 133 ft. high. This grand crag, probably the finest exposure of Pebble Beds in the Midlands, is composed of yellow sandrock, which contains many pebbles and is strongly jointed, the joints running approximately N. 5 deg. W. East of the Castle the bluff disappears for a space, giving place to a hollow, which probably held at one time a small tributary, descending to the Trent Valley, where *Carrington Street* now is, but the feature reappears as a low cliff behind *Broad Marsh* and *Leen Side*, and is very prominent at *Sneinton Hermitage*, where there are again caverns behind the *Rock Houses*.

A small inlier of Bunter is brought in by a fault at the foot of *Hungerhill Gardens*, where a bank on the waste ground E. of *Sycamore Road* shows 6 ft. of Pebble Beds.

Mr. E. Parry, C.E., informs us that the foundations for the Great Central Railway Bridge over the Trent passed through 10 or 12 ft. of river gravel and reached the Bunter at a level of about 51 or 52 ft. above O.D., but the level of the rock at the abutments varied from 57 ft. on the north side to 52 ft. on the south side.

The topmost portion of the Bunter was recently well seen in a section at Sneinton Vale to be subsequently described (p. 37).

Some further details respecting the occurrence of the Bunter rocks beneath the gravels of the Trent Flat and in borings at and near Nottingham will be found in a subsequent chapter (see p. 81).

R. L. S.

Keuper.

General Account.

Owing to the low dip and consequent breadth of outcrop, the thickness of the Keuper formation is difficult to ascertain, except where it has been pierced in deep borings. One of these borings, which passed through the whole of the Keuper, was made at Owthorpe, and afforded direct evidence as to the thickness of the formation south of Nottingham. The site of this boring is in the adjacent Sheet (No. 142), but is only two miles south of the margin of the present map. It showed that the Keuper Marls are 627 ft. thick, and the lower division of the Keuper—the Waterstones—122 ft., so that for the whole of the Keuper we have here a thickness of 749 ft. As compared with its development in Cheshire,[1] where the formation attains a thickness of over 2,400 ft., the Keuper of the Nottingham district shows considerable attenuation, sharing, though in

[1] A. Strahan, 'Geol. of the Neighbourhood of Chester' (*Mem. Geol. Surv.*), 1882.

a less degree, the attenuation which we have already noted in the Bunter and in the Permian rocks of the district. The general dip of the beds is towards the south-east at a very low angle, varying from about half a degree to two degrees, and on the average is probably somewhat less than one degree.

The junction of the Keuper with the Bunter in the Nottingham district, as already noted, is sharply marked, and appears to denote that there was some erosion of the underlying Pebble Beds preceding the deposition of the Waterstones. Locally we find lenticular patches of conglomerate, from an inch or two up to two feet in thickness, lying in hollows of the Pebble Beds and immediately surmounted by the evenly-bedded, flaggy Waterstones, in sharp contrast with the irregularly current-bedded sands and pebble-bands of the Bunter.

There is further evidence of unconformability or overlap in the slightly different strike of the two formations shown by the mapping. In fact, here, as in Cheshire,[1] the sharpest line of division within the limits of the Trias occurs at the base of the Waterstones, and must correspond to some wide-reaching change in the physical conditions.

There has been much discussion with respect to the Basement Conglomerate of the Keuper around Nottingham. In the first edition of the previous Geological Survey Memoir (on Quarter-sheet 71 N.E.: Old Series), published in 1861, the bed was not separately described, though the occurrence of pebbles in the base of the Keuper was mentioned.[2] Subsequently, the researches of the late J. Shipman, alone and in collaboration with E. Wilson,[3] brought this conglomerate into prominence; and in a later edition of the Survey map published in 1879, and of its accompanying Memoir, published in 1880, the Basement Beds were separated out as an independent subdivision, to which the term "Keuper Conglomerate" was applied; and Mr. Shipman's descriptions of some of the sections on which he laid particular stress were given in his own words. But it has since been urged by Prof. Blake[4] and others[5] that Mr. Shipman's classification of the beds could not be sustained, as it included deposits inseparable from the Bunter in some instances, and even, in one case (at Annesley Park) belonging to the Glacial Drift.[6]

Shipman proposed to include with the Basement Beds of the Keuper some white sands with pebbly layers underlying the conglomeratic band at the base of the Waterstones; and he considered that these beds were unconformable to the Bunter, and might be an attenuated representation of the Lower

1 See 'Geology of . . . . Chester,' *supra cit.*

2 *Op. cit.*, pp. 17, 18.

3 E. Wilson and J. Shipman, 'On the Occurrence of the Keuper Basement Beds in the Neighbourhood of Nottingham,' *Geol. Mag.*, dec. 2, vol. vi, p. 532.

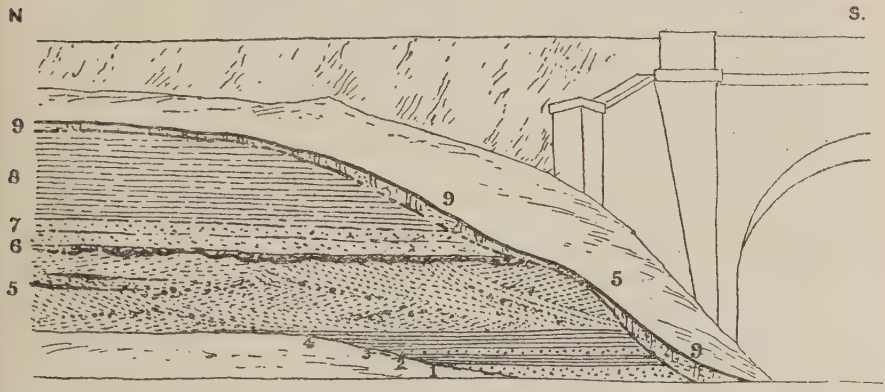
4 J. F. Blake, 'Report of Excursion to Nottingham,' *Proc. Geol. Assoc.*, vol. xii, 1892, p. 386.

5 'Geol. Southern Part of Derbyshire and Notts Coalfield' (*Mem. Geol. Surv.*), 1907, p. 126.

6 J. Shipman, 'The Story of the Hemlock Stone,' *Trans. Nottingham Naturalists Soc.*, 1844, p. 11.

Keuper Sandstone or Basement Beds of Cheshire.[1] But even in Cheshire it is now recognised that the so-called Keuper Basement Beds are more nearly allied to the underlying Bunter than to the overlying Keuper.[2] Both lithologically and stratigraphically, it is inconvenient to include any of the current-bedded pebbly sands below the Waterstones with the Keuper; and local unconformabilities, due to contemporaneous erosion, are so common in the Bunter Pebble Beds, that the phenomena observed by Shipman do not justify the separation of these

Fig. 3.—Section on W. side of Great Northern Railway Bridge, Colwick Road, Sneinton, showing Junction of Keuper and Bunter.



		Ft.	In.
	9. Weathered clayey loam soil and downwash, the latter increasing to 5 ft. in thickness on the lower slopes - - average	1	6
	8. Regularly-bedded red and grey marl, with thin sandy partings increasing in frequency downward - - - - - - -	10	0
	7. Greenish-yellow flaggy sand-rock, with black streaks, evenly bedded, resting with sharp contrast on the current-bedded Bunter - - - - - - - - - - - -	3	0
	6. Lenticular seam of red marl and grit with small pebbles, chiefly quartz - - - - - - - - - 2 in. to	1	0
Bunter Pebble Beds.	5. Grey and greenish sand and sand-rock, strongly current-bedded, with small and large pebbles both scattered and in bands and lenticles; also with impersistent streaks of red marl, 1 in. to 3 in. thick, containing traces of plants (see p. 42) locally broken up and distributed in cakes and rolled lumps among the quartzite pebbles - - - - - - -	10	0
	4. Stratified red and greenish grey marl, with a lenticle of brownish sand - - - - - - - - - - - -	3	0
	3. Pinkish-grey sand-rock - - - - - - 6 in. to	0	10
	2. Stratified deep red and greenish grey marl - - 10 in. to	1	0
	1. Coarse pebbly sand-rock (normal Bunter Pebble Beds), exposed only in the road to the cutting - - - - - - - -	3	0

upper beds from the Bunter (see Fig. 3). We therefore now include all these current-bedded pebbly sands with the Bunter, and regard the base of the evenly-bedded Waterstones, or the underlying thin conglomeratic layer where it is present, as the lowest bed of the Keuper in the Nottingham district.

[1] A. Strahan, 'Geol. of the Neighbourhood of Chester' (*Mem. Geol. Surv.*), 1882. p. 5.

[2] A. Strahan, 'On the Lower Keuper Sandstone of Cheshire,' *Geol. Mag.* dec. 2, vol. viii, 1881, pp. 396 and 574.

Near the northern margin of the present map, a band of grey sandy clay sets in at the base of the Waterstones, and is then persistent northward for many miles throughout the adjacent Sheet (No. 113), where it is dug in several places for brick-making. It is nowhere clearly exposed, however, in the Sheet dealt with in this Memoir, and its further description is therefore held over for the Memoir on Sheet 113.

The Waterstones are well exposed in the railway cuttings in the eastern suburbs of Nottingham, and in some of the deep "dumbles" at the head of the little streams on the north-western side of the Trent. From a bed near their base at Colwick Wood, in a tunnel in connection with the sewage works, the late E. Wilson obtained numerous remains of small fish, a discovery of peculiar interest, as this is the only known instance of the occurrence of undoubted fossils in the Keuper in the district. The fish were described and figured by Mr. E. T. Newton, F.R.S., as *Semionotus sp.* and a palæoniscoid species, the latter being represented by scales only.[1]

Wilson's account of the circumstances of the discovery contains the following passage:—"They come from the Lower Sandstone or 'Waterstones,' of the Upper Keuper, which at this point rest upon the 'Basement Beds' of the Lower Keuper. The fishes were apparently limited to the lowest stratum of the 'Waterstones,' a bed of greenish-yellow sandstone 10 in. thick, with intercalated streaks of red and green marl, and a seam of pebbles at its base, and to the bottom inch or two of that stratum." He remarks that the same bed can be seen cropping out in an adjoining field but is not there fossiliferous, nor has the horizon proved fossiliferous at any of the numerous other places near Nottingham where it has been exposed, and he continues, "there were two points specially noticeable in connexion with the occurrence of these fossils in the Keuper at Nottingham; namely, first, the great number of the fishes, there being quite a shoal of them for a distance of thirty feet or thereabout, in the line of section, the individual fishes even lying over one another in the middle portion of that distance, but gradually becoming more widely separated in either direction until they finally came to an end; and, secondly, their occurrence at the junction of two sub-formations of the Trias, namely, of the Waterstones of the Upper Keuper and the Basement-beds (Lower Keuper).[2] This may be, and probably is, merely an accidental coincidence. At the same time, it may be worth while to record the fact. The two series of deposits, at the junction of which this fossil shoal of fishes was found, are of very diverse characters, and were formed under very different physical conditions." "The Waterstones, ... (at the base of which the fishes occurred, and to which series they belong), are regularly bedded fine-grained sandstones and marls, showing ripple-marks

[1] *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 537.

[2] The best specimens of these fish are now preserved in the Nottingham Museum; other specimens are in the Museum of Practical Geology, Jermyn Street, S.W., and in the museums at Southwell and Leicester.

and suncracks, and were evidently formed in waters which were tranquil but extremely shallow, and liable to entire and perhaps rapid desiccation. These waters were in all probability those of saline lakes or lagoons. Possibly the fishes found at Colwick may have become entrapped in the shallows of such a lake, and killed in numbers by the drying up or the increasing salinity of the water." Mr. Wilson adds in a footnote that he also found in the same beds at Colwick the cast of a stem of a land plant having the appearance of *Equisetites columnaris*. A labyrinthodont footprint was likewise found by the Rev. A. Irving in these Waterstones in the cutting on the Midland Railway at Colwick.[1]

The Keuper Marls, though of a clayey texture, are in composition not strictly clays, but calcareous mudstones containing a large quantity of siliceous silt or exceedingly fine-grained sand, which in places is concentrated into definite bands of "skerry," or calcareous loamy sandstone, usually of a greyish-green tint. These hard bands are very numerous in the lower part of the series, and become more widely separated in the higher part. A good example of the previously mentioned flat-topped features (p. 6), due to the presence of these resistant beds in the marl, is afforded by The Plains[2] near Nottingham, a little plateau dipping very gently towards the S.E., which is bounded on every side by a steep escarpment and sharply notched by the small streams draining to the Trent.

The best sections of Keuper Marl are those in the Nottingham brickyards. On the east and north-east sides of the city the lower portion of the deposit is excavated, whilst south of the Trent, about a mile south of West Bridgford, the workings are in a higher belt. The topmost beds of the formation are best exposed in the gypsum pits at Newark.

G. W. L. and R. L. S.

The south-easterly dip carries all the lowest portion of the Keuper Marl beneath the surface in the valley of the Trent, so that the beds which rise above the alluvium on the south-east side of the Trent Flats represent the middle and upper parts of the formation, the thickness of the marl outcropping on this side of the river being about 450 ft. to 500 ft. The lower beds of this area are best seen between Kneeton and East Bridgford, and a fair idea of the succession up to the base of the Rhætic can be formed by following the line of the section shown in Fig. 4.

At the base of the Trent cliff, up to about the 100 ft contour are platy marls, with thin sandstones and veins of gypsum which become less abundant towards the top. These strata are overlain by thick beds of dark-red massive marl-rock alternating with sandstones, up to the 250 ft. contour. Two of these beds of marl-rock are conspicuous in the west slope of Old Hill, where they form the face of steep scarps capped with sandstones. The uppermost of these sandstones forms the sandy dip-slope of Old Hill descending towards Carcolston. On the lower part of this

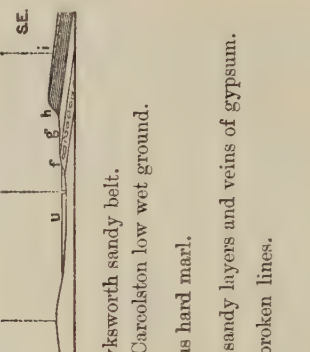
[1] A. Irving, 'The Geology of the Nottinghamshire District.' *Proc. Geol. Assoc.*, vol. iv, 1857, p. 73.

[2] *Mapperley Plains* on the new map.

dip-slope, east of the Foss Way, the sandy beds are capped with clay, and the drainage of the slope, sinking into the sandstones,

Fig. 4.—Section across the Keuper Lowland from the River Trent near Hoveringham to the Rhætic Escarpment near Elton.

Horizontal Scale, 1 *in.* = 1 *mile*. *Vertical Scale*, 5 *times the horizontal*.



U. Alluvial Flats.
i. Hydraulic Limestones, base of Lower Lias.
h. Rhætic Beds.
g. "Tea-green" Marls.
f. Main gypsiferous belt.
e. Scarrington and Hawksworth sandy belt.
d. Marl underlying the Carcolston low wet ground.
c. } Bands of homogeneous hard marl.
b. }
a. Platy marl with thin sandy layers and veins of gypsum.

The principal "skerries" or beds of sandstone are indicated by broken lines.

passes beneath this clay-capping and bursts out in springs along the lower part of the slope, forming an area of marshy soil.

Passing south-west along the line of the section, we ascend the minor skerry-feature of Car Hill, and then, crossing the Car

Dyke alluvium, come to the Scarrington and Hawksworth sandstone, which seems to be much less strongly cemented than the other "skerries" of the district, and weathers to a red sandy soil without any rubble. This is the highest sand bed in the Keuper within the limits of the map, the 120 ft. or so of marl above this horizon being, as far as could be seen, of a pure, fine-grained type. About 30 ft. below the base of the Rhætic, and attaining in places a thickness of 60 ft., is a series of red marl strata containing massive gypsum beds, apparently of original deposition. The marls for some distance below the Rhætic shales are of a uniformly pale "tea-green" colour.

Reviewing the whole sequence of the Keuper Marl we thus find that the lower beds above the Waterstones contain many more sandstones than those in the middle of the series, while the upper beds are almost entirely free from them. This absence of anything but the finest sediments in the upper beds of the Keuper indicates deposition at some distance from the shore, and points to the wider extension of the water-area during the deposition of the higher portion of the series. The extensive deposits of gypsum near the top of the series seem, however, to indicate the desiccation of these waters and the concentration of their mineral contents toward the close of the period, shortly before the setting in of the conditions which led up to the transgression of the Rhætic sea.

In the only section where the junction of the Keuper and Rhætic is visible there is a sharp line of demarcation between the two, but no decisive indication of erosion.

W. B. W.

The "Tea-green Marl," which constitutes the top of the Keuper Marls, was formerly considered to belong to the Rhætic Series, and was classed along with the Rhætic as the basal subdivision of the Lias. This method was in vogue during the previous mapping of the Quarter-sheet 71 S.E. by the Geological Survey, but in the later work in Sheet 70 (Old Series) it was abandoned, and the Rhætic was mapped separately, as at present. The difference of method must be borne in mind in comparing the present map with its first-mentioned forerunner.

In none of its physical characters, except colour, does the Tea-green Marl differ from the underlying red marls, which are themselves frequently streaked and blotched with the same green tint; but at the top of the Tea-green Marl there is a sudden change of lithological character in the black papery shales of the Rhætic. In the present map this junction is now clearly exposed only at Beacon Hill, Newark, but was formerly seen and described by E. Wilson[1] at Cotham and Barnstone.

The question of the coloration of the Tea-green Marl has been the subject of much discussion. The point at issue is whether the colour is that of the original sediment, or whether it is due to secondary change in the iron compounds after the deposition

1 E. Wilson, 'The Rhætics of Nottinghamshire.' *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 451.

of the beds; and if the latter be the case, what the character of the change has been. By Maw [1] the green tint was supposed to be due to secondary alteration from an original red colour; while Dr. Moody [2] supports the view that the change has taken place in the red marls, which have had their original green tint altered to red by the addition of iron from chalybeate water. The subject is too wide to be dealt with here, but some facts observed in the Newark district were in favour of the first-mentioned hypothesis.

R. L. S.

Details.

Area north of the Trent.

Keuper Conglomerate.—Our knowledge of the conglomeratic bed at the base of the Waterstones in this area is derived wholly from temporary artificial sections. At the time of writing (1906-7) the only section visible is that illustrated in the foregoing figure (Fig. 3, p. 37), near the Great Northern Railway bridge across the Colwick Road.

In this section probably the whole of the beds above the lower band of marl (bed 2 of Fig. 3) would have been included by Shipman in the "Keuper Basement Beds," in spite of the resemblance of the overlying material (bed 5) to the Bunter. On the grounds already stated (p. 37), we consider that the thin lenticular pebbly band (bed 6) represents the base of the Keuper, and that all the beds below it should be included in the Bunter Pebble Beds. Marl bands are not uncommon in the Bunter (see p. 34), though that shown as bed 4 in the section is thicker than usual. The records of deep borings show (Appendix I, p. 111), however, other similar instances.

A feature of much interest in this section is the occurrence of plant remains, which, as previously mentioned, are the only contemporaneous fossils hitherto found in the Bunter of the district. They were obtained recently by Mr. R. D. Vernon, of the Nottingham University College, from the lenticular and broken bands of red marl indicated in bed 5 of Fig. 3. Owing to their poor state of preservation, it is doubtful whether they can be specifically determined; the best preserved fragments appear to represent portions of the stems of a plant allied to *Equisetites*. We understand that Mr. Vernon intends shortly to publish a fuller account of his discovery, and our thanks are due to him for permitting us to make mention of it here.

During recent building and drainage operations in Mapperley Park, the junction of the Bunter with the Keuper was cut across in several shallow excavations. From some of these, hard blocks of pebbly calcareous conglomerate were thrown out, representing the cemented top of the Bunter or the base of the Keuper, but there was nothing distinctive in their aspect.

Further details regarding occasional exposures of the bed may be found in a paper by Wilson and Shipman. [3]

G. W. L. and R. L. S.

Waterstones.—These beds are constant in character throughout the district. As above mentioned, their base was recently well exposed at *Sneinton Vale* (Fig. 3). The upper limit is always indefinite, owing to the gradual passage of the sandy beds into marl, so that it is impossible to fix this limit with precision, and therefore the line adopted on the map must not be too strictly interpreted.

1 G. Maw, 'On the Deposition of Iron in Variegated Strata.' *Quart. Journ. Geol. Soc.*, vol. xxiv, 1868, p. 351.

2 G. T. Moody, 'The Causes of Variegation in Keuper Marls,' etc. *Quart. Journ. Geol. Soc.*, vol. lxi, 1905, p. 431.

3 'On the Occurrence of the Keuper Basement Beds in the Neighbourhood of Nottingham, *Geol. Mag.*, dec. 2, vol. vi. 1879, p. 532.

West of the Dover Beck, a few feet of sandy flaggy Waterstones are exposed in the road from Calverton to Woodborough; also S.W. of Spring Cottages, Calverton; and again in the road and stream-banks near Woodborough Hall. At Red Hill, a deep cutting on the Mansfield-road shows 10 ft. of fine-grained, grey-brown sandstones, interbedded with marl, and resting on 2½ ft. of red marl.

The Great Northern Railway tunnel through the Keuper escarpment between Daybrook and Gedling, shows good sections at both ends, the cutting at the N.W. end revealing about 60 ft. of Waterstones, dipping at 1 deg. to S.E., with a few inches of soft, sandy conglomerate containing quartzite pebbles, at their base, resting on Bunter. The Suburban Branch line of the same Company has a succession of small cuttings in Waterstones north of Sherwood Station. At the station itself the rock has a dip of about 1 deg. S.S.E., and is more thickly bedded than usual.

Between Carrington Station and Hungerhill Gardens there are several small sections, and the old Rifle Range shows about 30 ft. of Waterstones dipping very slightly towards N.N.W. On *Coppice Road*, and in a small disused quarry in a field behind the gardens on the east side of the road, there are other small sections. The S.E. end of the Great Northern tunnel under The Plains opens into a cutting, now much obscured but still showing very thinly-bedded and "skerry"-like micaceous sandstones, often ripple-marked. Another deep but short cutting ¾-mile further S., now overgrown, is in the passage beds between the Waterstones and marls.

A good section is seen in the two quarries at the Bulwell Brick Company's Works in *The Wells Road*, the upper being in Keuper Marl and the lower in Waterstones, including the passage-beds near the top of the series. The lower quarry shows:—

	ft.	in.
Thinly-bedded, grey-brown sandstone, with bands of marl	30	0
The same, but weathered red	9	6
More thickly-bedded sandstone, grey-brown internally but weathering red. The thickest bed is 3 ft. 10 in., and is near the bottom	23	6

All along their outcrop small temporary exposures of the Waterstones are frequently made during building and draining operations in the northern and eastern suburbs of Nottingham, and many are recorded in the MS. notes of the late James Shipman, now preserved in the University College. The short cutting on the G.N. Ry. north of Colwick Road is overgrown, but shows an alternation of sandstone and marl, the former predominating. The dip here is 2 deg. to the south.

The steep edge of the Trent Valley, at the foot of which runs the Lincoln branch of the Midland Railway, is composed of Waterstones with a capping of Keuper Marl. The beds are well exposed along the railway, and in one place a band streaked with gypsum is brought up by a fault (p. 23). In the villages of Carlton and Gedling, red sandy flags with marly partings are exposed in numerous small sections in the streets and behind the houses.

The two ravines at Lambley, occupied by the streams which unite to form the Cocker Beck, are cut down into the top of the Waterstones, which are also exposed in the banks of the Cocker in several places between Lambley and Lowdham. Usually the beds are so nearly horizontal that the dip is hardly perceptible, but at one place in Lambley Dumble the flaggy sandstones and marl are bent into sharp contortions of small amplitude, and show dips of as much as 50 deg. Similar sharp local contortions were observed to affect the lower portion of the Keuper Marls in a deep gutter 300 yds. S.W. of *Rudduck Farm*, west of Burton Joyce; and again, further north, in *Priory Dumble*, Thurgarton, 400 yds. W. of Checkers; and also west of Bankwood, and in Halloughton Dumble, south of Halloughton Wood. At all these places the disturbance occurs in the bottoms of valleys overlooked by high banks or steep slopes, and although the contortions may be due to the proximity of undetected faults, it seems more probable that they represent superficial crumpling due to a slight

"creep" of the beds in the ravines under the superincumbent weight of the valley-sides.

R. L. S.

From Burton Joyce north-eastward, the top of the Waterstones is supposed to occupy the lower part of the high Trent bluffs continuously to Gonalston, where it descends to the river flat and is hidden by alluvium. The exposures along this belt are few and generally obscure; and the strata when seen are of the indefinite character usual at this horizon, varying between thinly-bedded sandstone with marl partings and thinly-bedded marl with sandstone partings. One of the best sections is in a cutting in the garden of a new house at Burton Joyce, on the steep slope 200 yds. N. of the Vicarage, where 12 ft. of flaggy sandy beds of Waterstone type are exposed. In the deep stream-gully N.W. of the village, the beds at a somewhat lower level contain a preponderance of marl, which is the condition also in a little gully at Bulcote. Between Bulcote and Lowdham a large excavation has been made in the bluff just above the level adopted for the top of the Waterstones, but the section is now obliterated. A little farther north, however, 500 yards W. of Lowdham Station, a small brickyard has been opened at the same horizon, showing about 15 ft. of red marl, streaked with greenish-grey bands and thin skerry, and with beds of red sandy loam, especially toward the base. The valley of the Cocker Beck here breaks the continuity of the Trent bluffs. On the opposite side of this little valley, where the bluff sets in again, 600 yds. N. of Lowdham Station, another brickyard was worked, but is now abandoned. The greatly obscured section still shows in places up to 15 ft. of red marl, loam, and grey sandstone-bands veined with gypsum in the lower part of the excavation, and similar beds for 10 or 12 ft. in the upper part, capped by a 2 ft. skerry of flaggy grey sandstone with gypsum veins. A well recently sunk to a depth of about 34 ft. at the foot of Barker Hill, 300 yds. farther north-eastward, is reported to have passed through clay with hard stone bands, and obtained a good supply of water which rose to the surface.

It is possible that the upper boundary of the Waterstones between Gedling and Gonalston has been taken at a somewhat higher horizon than the boundary adopted at the main escarpment to the north and west, where exposures are very rare and the mapping has depended almost entirely upon the surface features. But even allowing for this factor, it is clear that the Waterstones increase in thickness eastward, as the boring of the Nottingham Corporation Waterworks at the outcrop of these beds on the Trent flat at Burton Joyce proved the base of the Keuper to be 153 ft. below the surface (see pp. 98–99), and at least 30 ft. must be added to this for the thickness allowed to the Waterstones in the adjacent hillside. Also at the Thurgarton boring, 4 miles distant north-eastward, these beds appear to have a thickness of not less than 150 ft. (see p. 113); while in a boring at Newark most of the lower 287 ft. of the Keuper is described as "sandy marl" and is therefore allotted to the Waterstones (p. 105). This increase may be due either to an actual thickening of the sediments or to the sandy conditions persisting higher up in the Keuper Series, or perhaps to a combination of both causes.

Along the main escarpment, the Waterstones are exposed in the deep gullies toward the head of the "dumbles," *e.g.* in Oxton Dumble, and in Halam Beck between Challands Farm and Halam, and in small artificial sections, such as the road-cuttings below Oxtonhill Farm and at Gonalston Hall. A well at Halam, 228 ft. in depth, reached the base of the Keuper at 118 ft., the remainder being Bunter.[1]

In the Southwell inlier the Waterstones are well seen in the banks of Westhorpe Dumble, and were recently excavated to a depth of 10 ft. or so in trenches for the drainage of Westgate, Southwell. Some sandy and marly flags sparingly exposed in the north fork of Priory Dumble west of Bankwood, and in Halloughton Dumble north of Bankwood, may possibly represent inlying strips of the top beds of the Waterstones; but even if this were certain, the inliers would be too small to be shown on the 1-in. map.

[1] Communicated by Mr. G. Hodson, C.E.

Owing to downwash from the overlying marls, the soil on the upper slopes of the Waterstones outcrop does not differ much from that of the marls, but it becomes more loamy on the lower slopes, and constitutes some of the best tillage land of the district.

G. W. L.

Keuper Marls.—The most northerly of the excellent brickyard-sections in the marl, in the vicinity of Nottingham, is at the Nottingham Patent Brick Company's Works, Dorket Head, which shows the following section :—

	Ft.	In.
Greenish-grey sandstone ("skerry")	2	0
Red marl	6	0
Sandstone	1	0
Red marl	8	0
Sandstone	1	0
Red marl	8	6

The different beds of marl vary slightly in texture and composition.

Another brickyard, now disused, on the Woodborough Road, at the boundary of the parishes of Lambley and Woodborough, exposes the upper "skerry" which underlies the little plateau known as "The Plains," and below it lie red marls with occasional thin bands of grey sandstone.

At the road corner near Wicketwood Hill, where three parishes meet, two wells have recently been sunk, one of which passed through 50 ft. of marl with skerries, the thickest occurring at a depth of 25 ft. and attaining a thickness of 1 or 2 ft.; some veins or bands of gypsum were met with near the bottom. The other well was sunk to a depth of 140 ft. through similar strata, gypsum being again met with, the first appearance being at a depth of 91 ft.

A succession of brickyard sections occurs along the Woodborough Road, from *Scout Lane* to beyond the Suburban Railway, in which about 61 ft. of Keuper Marl of the usual character is visible. The following will serve as an example of these sections :—

Nottingham Patent Brick Company, Mapperley Works.

	Ft.	In.
Soil	0	9
Red marl	3	0
Sandstone	5	0
Red marl	4	0
Grey sandy marl	2	0
Red marl	4	6
Grey sandy marl	1	0
Red marl	3	0
Grey sandy marl	0	6
Red marl	5	6
Grey sandy marl	2	0
Red marl with a grey film at its base	4	6
Red marl	4	6
Grey sandy marl	2	0
Red marl	6	0
Red marl, soft, with green patches	5	0

Extensive brickyards at *Standhill*, Carlton, show about 50 ft. of red marl with thin skerries, including the top skerry which forms the plateau. These sections are interesting from the presence of a belt of marl containing anastomosing veins of gypsum. Apparently the same horizon is seen in a disused brickyard north-east of Thorneywood Station.

The Great Northern Railway on emerging from the tunnel N. of Thorneywood Station runs in a cutting which is either in the uppermost Waterstones or in the lowest part of the marl. A small fault probably crosses the line at the Carlton Road Bridge, for the southerly dip of 2 deg. to 3 deg. at the station gives place, S. of the bridge, to one of 3 deg. to the north. A little farther S. the section shows a belt of gypsiferous marl

which appears to be the same as that mentioned above. The beds here are thrown into gentle folds in consequence of a fault which may still be made out in the cutting at a point 600 yds. S. of Thorneywood Station.

In a brickyard at *The Wells Road*, the upper quarry falls within the boundary adopted for the base of the Keuper Marls, though the beds are mostly of sandy texture, thinly interstratified with marl. Strata of this character are seen to a depth of 56 ft., but at the bottom of the quarry a thicker bed of sandstone without stratification is exposed which is regarded as the top bed of the Waterstones. The section in the lower quarry has already been described (p. 43).

R. L. S.

The upland of Keuper Marl north-west of the Trent is broken across by the valley of the Dover Beck, which is lined on both sides by the Waterstones. The high ground to the north and south of this valley presents the characteristic configuration of the Keuper Marl country—steep slopes, often with sharply defined upper margins, edging the flattened summits. When viewed on a wide scale, these tabular summits are seen to descend gradually towards the south-east, and they represent approximately the dip-slope of the marls. In some cases it can be proved that a particular band of skerry, a few inches in thickness, has given rise to the feature, but often the suspected skerry is not more in evidence along the edge of the feature than over any other part of the marl. Agricultural operations may be partly responsible for this, as the slabs of hard skerry are removed when they are sufficiently near the surface to impede the plough; but it is likely also that some beds of marl, particularly those associated with the sandy skerries, are in themselves more compact and unyielding than others, and therefore assist to produce the features. There seems to be one horizon of this kind about 50 ft. above the top of the Waterstones, and another at about 100 ft. above the same boundary; and it is to one or the other of these horizons that the principal skerries shown on the map may be assigned.

Sections are rare on this upland, and consist mainly of small exposures in shallow road-cuttings, stream-banks, ponds and ditches, with an occasional well-sinking. The strata revealed are monotonous in character—banded red marls alternately compact and loamy, here and there blotched with green or streaked with greyish-green layers, usually of a more or less sandy texture. The thicker skerry-bands have frequently a porous structure, being full of small irregular cavities from which apparently some soluble constituent has been removed; and occasionally their surfaces are rugged with sharply cubical pseudomorphs after crystals of rock-salt. Thin irregular veins of gypsum are abundant in the lower part of the series, a little above the top of the Waterstones, *e.g.* in the sections at Lowdham already described (p. 44); but this mineral has not been found in workable quantity in the district north of the Trent.

Towards the valley of the Greet, the surface features lose their sharpness, so that it was not found practicable to trace the skerry-bands continuously in this quarter. It is possible that the features may here be modified by the remnants of glacial drift, as the soil is in places full of pebbles (see p. 75), though the marl, as usual, lies close beneath the surface.

It will only be necessary to mention a few of the deeper sections as typical of the exposures in this part of the map. At Thurgarton, a cutting on the steep rise of the road to Southwell and a second road-cutting 200 yds. further W., show about 10 ft. of red and greenish marl with thin sandstone bands. At Goverton, a small pit at the S.W. corner of the fox-cover reveals 8 ft. of similar marl with flaggy layers of fine-grained grey sandstone. Most of the dumbles between Dover Beck and Southwell present occasional sections of the marls, which are deepest and most continuous toward the head of the dumble.

The recent main-drainage trench from Southwell, along the S.W. side of the railway down the Greet Valley, was excavated partly in the marls, covered by a few feet of stony loam with occasional boulders (see p. 75), beneath which the surface of the marl was much disturbed and broken. At Southwell the lower portion of the Keuper Marl has been dug for brick-

making in the steep rise N. of Westgate, and at the spot where the work is still in progress, red marl with damp loamy bands and thin grey skerry layers is exposed to a depth of about 15 ft., with a stronger skerry about a foot in thickness towards the top of the section. The last-mentioned skerry appears to be that which has been traced at this horizon—about 50 ft. above the top of the Waterstones—along the main escarpment of the marls west of Southwell. It is exposed, among other places, in a cutting on the high road 400 yds. S.E. of Halam, and in a pond at the edge of the escarpment 600 yds. N.E. of Thorny Abbey.

A well-boring at Norwood Hill, between Southwell and Halam, starting near the base of the Keuper Marl and passing down into the Waterstones gave the following section[1] :—

	Ft.
Red marl and sandstone	53
Sandstone	7
Sandy marl	1
Sandstone and red marl	4
Coloured shale and sandstone	11
Mixture of shale and sandstone	4
	80

A well at Brackenhurst, one mile S. of Southwell, starting in the red marl, passed through 358 ft. of Keuper before reaching the Bunter, which was penetrated to a further depth of 72 ft.[2]

G. W. L.

AREA SOUTH OF THE TRENT.[3]

West of Radcliffe.—In the high river bluff at Clifton Grove, red marl, with an occasional greenish skerry-band, is sparingly exposed by landslips. This high bank sinks down abruptly to the alluvial flat of the Fairham Brook ; and east of the brook the Keuper Marl rises gently from the Trent alluvium, but is covered for the most part with loamy soil, becoming in places sandy and gravelly, from the downwash of drift or later superficial deposits now destroyed by weathering.

The Great Central Ry. main line, on leaving the Trent flat, commences to cut into the Keuper Marl, but the cuttings which fall within the map are shallow and show little. A brickyard east of the railway, about ¾ mile S. of Wilford, reveals 30 ft. of marl, practically horizontal, with two or three bands of greenish sandstone, each about 1 ft. thick.

The Midland Railway runs in a cutting in the marl to Edwalton Station and beyond it, but this cutting is now grassed over. When this section was clear, Shipman noticed a fault in the marls at the second mile-post from Nottingham. In a brickyard which has been opened between the railway and the high road, ½-mile N. of Edwalton Station, about 25 ft. of red and variegated marl is exposed, beneath a thin capping of sandy soil. At a depth of 6 ft. from the top of this section a conspicuous band of whitish shaly sandstone with partings of greenish marl is exposed. The thickness of this sandy belt varies somewhat in different parts of the pit, its maximum being about 7 ft. On the opposite side of the Melton Road a small excavation shows about 8 ft. of similar sandy beds. The prolongation of the belt both eastward and westward is indicated by the character of the soil in the fields and by a slight feature.

The marls have been trenched in several places, beneath an irregular covering of post-glacial valley-deposits, in laying the drains for new streets in the southern part of West Bridgford. Further to the eastward, until Radcliffe is reached, the exposures of Keuper are insignificant, and the only

1 Communicated by Messrs. Le Grand and Sutcliffe, per Mr. W. Whitaker, F.R.S.

2 Communicated by Mr. G. Hodson, C.E.

3 Principally by W. B. Wright, with contributions by R. L. Sherlock for the districts west of Radcliffe, and between Flintham and Newark.

one deserving mention is the small cutting along the Tollerton Road, 350 yds. S. of the canal. R. L. S.

Between Radcliffe and Kneeton, and south-eastward up to the Rhætics.—The lowest beds in this tract are partially exposed at intervals in the high river-banks between the villages of Kneeton and Radcliffe. The lower portion of the river-cliff in the neighbourhood of Kneeton, up to the 100 ft. contour, is composed largely of platy red, white, and green marl, with sandy beds and sandstones, and thin streaks of fibrous gypsum; but above this level the scanty exposures show a massive dark-red marl-rock. Above this hard marl is a bed of sandstone about 2 ft. thick, fine-grained and white below, but red and grey and more strongly cemented in its upper portion; and a few feet higher another rock-band occurs, of peculiar character, composed of gypsum and sandstone cemented by gypsum, in all about 12 in. to 18 in. thick. These beds are best seen in the sunken lane between Kneeton and Hoveringham Ferry. They can be traced S. from Kneeton round the N.W. face of Toot Hill, and here pass into the Trent cliff, where there are some small exposures. The gypsiferous vein is evidently very variable, being here represented by an 18 in. bed of a peculiar black-veined gypsum or gypsiferous sandstone, with 3 ft. of whitish-grey sandstone close by at about the same level. About 100 yds. farther south 3 ft. or 4 ft. of the whitish sandstone is exposed, and appears to be overlain by grey marl and sand, with a 5 in. gypsum vein, while, near by, the black-veined gypsum is seen to lie directly on the white sandstone.

To the south of Toot Hill this sandstone caps a well-marked scarp, generally 100 to 200 yds. from the top of the river-cliff. The face of this scarp is composed of homogeneous red clayey marl, to the softness of which, as well as to the resistant qualities of the overlying sandstone and gypsum, the feature is due. This feature is continued southward through East Bridgford, where the homogeneous red marl is well exposed at the top of the sunken road leading down to Gunthorpe Bridge. South-west of East Bridgford the feature forms a steep slope at the top of the gentle rise of Keuper Marl, which bounds the Trent Flat at Shelford. In this locality the clayey slope occupied by the red marl is known as "*The Devil's Coach Road*" owing to its barrenness and to the tendency of the corn grown upon it to dry up prematurely in the summer. This effect is apparently due to the steepness of the slope, from which the soil is continually being washed, and not to the composition of the bed itself, for in places along this horizon very extensive pits have been worked at the time when it was the custom to use marl as a manure; and material of excellent quality is said to have been obtained from them.

The same belt can be traced beneath its accompanying skerry round the northern face of Malkin Hill and thence southward towards Radcliffe, where its dip brings it down into "The Cliffs," and it is again sparingly exposed. Some small springs, one of which is known as *Hollow Well*, are thrown out on the slope from the base of the overlying skerries, apparently draining from the dip-slope of Malkin Hill, and issuing at the lowest point of outcrop of the porous sandstone. Throughout the 6 miles or so over which the above-described belt has been traced, the nature of the overlying skerry varies considerably, but the marl-rock seems to be very constant in character.

To return to the section at the Kneeton sunk-lane: it will be found that a higher series of skerries, in all about 18 in. thick, occurs at some distance above that already described, with still another smaller one just above. These are probably the same as the sandstone bands which cap Toot Hill and Old Hill, S. of Kneeton; and they also are underlain by a belt of hard red marl.

In the section along the sunken road known as *Trent Lane*, descending from East Bridgford to Gunthorpe Bridge, the marl of the "*Devil's Coach Road*" horizon is the highest bed seen. Below it are platy marls with thin green sandstones, becoming more abundant as we descend, and these harder bands have produced a sloping platform feature at the base of the escarpment.

The gypsiferous belt seen in the cliffs N. of Kneeton is not visible in

Kneeton Lane, owing to the obscurity of the lower portion of the section, but can be traced at the bottom of the river bank S. of Kneeton by Toot Hill and Old Hill. It appears to die out or sink beneath the level of the river before reaching East Bridgford, the most southerly indication of it having been seen at Shelford Manor boat-house, ½ mile below Gunthorpe Bridge, where gypsum was thrown out of an excavation a little above the level of the river. The abandoned pits and workings known as *The Potteries*, ½ mile lower down the river, are marked as gypsum pits on one of the old 1 in. maps, but there is not now any exposure of gypsum to be seen in them.

Gypsiferous strata are visible again in the river banks W. of Malkin Hill, below the belt of marl-rock previously described. The lower half of the river-cliff here shows the following section :—

	Ft.
Platy red and green marl, with some thin sandstone and many gypsum veins - - - - 10 to	15
Soft red marl, with some small gypsum veins - - -	10
Platy marl, with much fine-grained sandstone, and gypsum veins up to 4 in. in thickness, especially in upper part - - - - - - - - -	10
Red marl, with no skerry and little gypsum - - -	5

The gypsiferous beds in this section, owing to their dip, appear to sink beneath the level of the river about ½ mile below Radcliffe Ferry ; about ¼ mile higher up the river the superincumbent marl rock and its capping of skerry in turn sink out of sight, and the strata above this zone are shown in the cliff from which the village of Radcliffe takes its name. This cliff-section shows altogether about 70 or 80 ft. of strata, though not all in one place. The three sections of separate exposures, given below, seem to represent approximately the whole series and are roughly conterminous, one leaving off where the next begins.

1. Section at top of cliff opposite the Ferry at Radcliffe :—

	Ft.	In.
Red and green sandy and loamy platy marl - -	10	0
Red loamy marl with two veins of gypsum - -	4	0
Red and green loamy and sandy marl and marl-rock with more abundant veins of fibrous gypsum - -	4	0

2. Section in middle of cliff opposite the Ferry at Radcliffe :—

Red and green marl, much veined with fibrous gypsum	15	0
Reddish brown sandstone - - - - - - -	0	9
Red and grey marl with a band of gypsum - -	3	0
Sandstone and marl with gypsum - - - 3 to	5	0
Soft red marl - - - - - - - - -	5	0

3. Section at foot of cliff 100 yds. below the Ferry at Radcliffe :—

Alternations of marl and sandstone, and soft and hard red marl - - - - - - - - - -	10	0
Soft red marl with intermittent 1 in. band of gypsum	3	0
Greenish marl with tiny layers of sandstone and veins of gypsum - - - - - - - - -	1	0
Red marl-rock ; hard below, softer towards top -	8	0
Sandstone, partly on shore of river - - - -	5	0

The gypsum and sandstone beds in the second of these sections form a resistant zone, which, when it rises out of the cliff, can be traced as a fairly prominent feature on the slope north of Radcliffe.

The skerries of the high ground S.E. of the Trent call for some remark. That which caps the plateau on which Trent Hills Farm

and Flintham Lings are situated is apparently on a higher horizon than the rest. So also is that which caps Toot Hill and Old Hill S. of Kneeton. At East Bridgford the dip-slope of the skerries which crown the escarpment containing the marl-rock is for some distance sandy and loamy: but about 100 yds. E. of the main street it is capped by a second rise, in the face of which there crops out a decidedly clayey bed. It appears to be this horizon which bears the "satinstone" vein of fibrous gypsum, mined in the village 100 yds. farther west at a depth of 25 ft. The overlying strata contain abundant sandy beds, their dip-slope having a remarkably sandy or sandy-loam soil as far as the Foss Way. Here, however, there appears to come on a capping of more clayey strata, which extends S.W. as far as Carcolston.

Through Carcolston a peculiar belt of marshy ground with shell marl and semi-alluvial clay runs along the line of strike, and creeps up the slopes. Many springs occur along this horizon, of which the best known is Newton Spring, near the old Roman Camp of MARGIDUNUM, the water being probably merely the rainfall on the East Bridgford and Kneeton skerries, which, sinking into the sandy strata, passes under the clay capping mentioned above and bursts out lower as a series of springs, causing the marshy soil.

South of Bingham there is a strong feature extending W. on the S. side of the Nottingham Road as far as Radcliffe, formed by the outcrop of a series of skerries, the relation of which to the East Bridgford and Kneeton skerries is not very clear. From Saxondale to Radcliffe this skerry belt is underlain by a considerable thickness of marl free from skerry. In the Harlequin Brick Pits the following section in the upper part of this zone is exposed :—

	Ft.	In.
Red marl with greenish grey bands, stiff and clayey in parts; with a pocket of drift pebbles at the top in one place	10	0
Skerry, dying out westward	0	5
Red marl with grey bands	12	0
Red marl, fairly pure	7	0
Marl of poor quality, with green bands	about 10	0
Good brick-marl	about 10	0

Some wells have been sunk at the foot of this section to a depth of 60 ft. without encountering any strong sandstone.

The sandy bed which runs from Hawksworth to Scarrington is a well-marked horizon in the Trias for a distance of about 9 miles. It is for the most part much more feebly cemented than the other skerries of the district, and weathers to a red sand quite free from stony rubble. The sandy dip-slope of this bed is in marked contrast with the stiff clayey ground of the escarpment which it caps. The decided feature which it forms is continuous southward to Scarrington, where it is displaced by the Elton Fault, but can be picked up again at Whatton, and traced past Wiverton and Tythby to Cropwell Butler, where it either dies out or is again displaced by a fault. Its peculiarly uncemented character makes it easy of recognition, and any doubt as to its identity N. and S. of the Elton Fault is set at rest by the fact that it is, in both districts, the highest sandstone in the Keuper.

Above this sandy bed the remainder of the marls, about 120 ft. thick, is decidedly clayey, and remarkably free from sand. It forms undulating ground which is much covered with alluvium and drift; but where these coverings are absent the soil is stiff and difficult to plough, though it is crumbled readily and brought into better condition by frost and other atmospheric influences. We gathered that where the soil contains stones, or, in other words, where the drift is present, it is not so readily affected by frost. Most of this marl is of a dark red colour with subsidiary green mottling, until the pale "Tea-green Marl" below the base of the Rhætic Shales is reached, where the red colour is entirely lost.

The gypsiferous horizon about 30 ft. from the top of the formation is best exposed in the neighbourhood of Newark (p. 53), but we shall first deal with the outcrop of these beds south-west of the River Devon.

In the bed of the Devon itself, ½ mile W. of Staunton, the gypsiferous strata are exposed in a section approximately 200 yds. in length, which commences at the Rural District Boundary about 200 yds. W. of the railway, and shows when the river is low at least three beds of granular gypsum. One of these is 15 in. thick, and there are also minor seams and balls of gypsum.

On the banks of the Smite, about ¾ mile due S. of Shelton Hall Farm there are traces of former gypsum pits. A well ¼ mile W. of Orston Windmill, and about the same distance N. of Orston Church, when deepened during the drought of 1905, cut a 6-in. bed of gypsum at a depth of about 20 ft.

Gypsum was at one time dug extensively in the village of Orston. In a well, 150 yds. E. of the church, a band 8 in. thick was met with at a depth of about 15 ft. and in a yard near the cross-roads S. of the church gypsum is reported at 5 ft., while in a well close by, 30 ft. in depth, it is said that several "plaster beds" were found. Some old workings about 120 yds. S.E. of the cross-roads do not now show any exposures of gypsum.

In the gypsum workings beside the railway ¼ mile W. of Elton and Orston Station, the top beds of the gypsum were well exposed, and a complete section of the strata which have been worked has been supplied by Mr. Almond, as follows :-

	Ft.	In.
Vegetable mould	2	0
Clay and brick earth	7	7
Rock with balls of plaster	5	0
Clay and marl	5	6
Coarse plaster	2	0
Marl with balls of plaster	7	8
Marl with balls of red stone	6	4
Marl with balls of plaster	5	0
Top White Rock	1	9
Marl	2	0
Marl with balls of plaster	1	6
Second White Rock	1	2
Marl	3	0
Blue Gypsum Rock	1	2
Marl	4	0
White Rock	1	0
	56	8

The strike of the gypsiferous belt at this spot is influenced by the Elton fault, and the outcrop may be supposed to throw out a loop westward round Blackberry Hill, beneath the alluvium, until cut off by the fault, near Aslockton. The uppermost beds of the belt are exposed to the S.E. of Blackberry Hill in Moor Dike, and in the adjoining ditch to the E., where massive gypsum, a foot in thickness, is visible for a distance of 150 yds. No exposure has been seen immediately S. of the fault, but about ½ mile W. of Sutton, and the same distance N. of Granby, there are some small overgrown pits in the face of a slight scarp, at the foot of which a waterhole shows a 5-in. bed of pure white granular gypsum.

Thin beds of gypsum have been recorded as occurring in the red marls in the cutting at Barnstone. Gypsum is also said to have been got in sinking a well at some cottages near the station ; and in a waterhole 400 yds. E. of Northfield House there is a 9-in. bed of granular and fibrous gypsum in red marl, 9 ft. below the level of the alluvium.

The gypsiferous zone swings westward, near the southern limit of the map, to the neighbourhood of Cropwell Bishop, where small exposures of

nodular gypsum are visible in the canal bank S.W. of Hoe Hill, and the ground to the N.W., W., and S. of the village is all cut up with old workings. The gypsum mine of the Gotham Plaster Company at Cropwell Bishop, near where the Nottingham Road crosses the canal, shows the following section :—

	Ft.	In.
Red and green marl	10	0
Marl impregnated and veined with gypsum	5	0
Red marl-rock	1	0
Fibrous and granular gypsum, with balls up to	1	0
Red marl-rock	5	0
Bright green gypsum, marly in places, used as roof 0 to	1	3
Red marl-rock up to	1	6
Balls of white and greenish gypsum	—	
Red marl-rock	2	0

A lower floor of gypsum 6 to 18 in. thick is reported to occur at 3½ ft. below the bottom of the pit.

The quarry and mine of the Snaith Plaster Works lies just S. of the limits of the map.

W. B. W.

Between Flintham and Newark.—In the tract adjacent to the Trent the general structure of the ground is similar to that already described in its prolongation south-westward, the Keuper Marls forming an undulating surface, with fairly definite features due to the outcrop of the harder skerries. The beds are, however, very scantily exposed in this quarter, though the higher portion of the Keuper is well seen in the gypsum quarries around Newark. A boring at Messrs. J. Hole & Co.'s brewery at Newark proved Keuper Marl to continue to a depth of 479 ft. from the surface (p. 105), and as the site of the well is about 100 ft. below the top of the marl, we obtain a total of about 580 ft. for the thickness of the marl at Newark. This is confirmed by the well at Messrs. Richardson's brewery recorded in the previous Memoir.[1]

At East Stoke a much overgrown gully known as Red Gutter, in the bluffs of the Trent, has been trenched into red marl, apparently free from skerry, excepting for thin lenticles at the top.

The skerries shown on the map give rise to the usual flat-topped little plateaux, and where they lie close to the surface on the gentle dip-slopes of these plateaux, they lend a sandy character to the soil. One of these sandstone bands is visible in the side of the short road running S.W. from East Stoke ; and others are exposed in the deep road-cutting between Flintham Lings and the Trent. The highest of these bands in the last-mentioned section supports the well-defined tableland on which Flintham Lings and Glebe Farm, Flintham, are placed, and which extends for 2 miles from the Trent in a very gradual dip-slope. On this flat the sandstone is revealed in several shallow pits, and is probably 1 to 2 ft. thick. A lower skerry forms the ridge on which Stoke Field Farm is situated, and is probably the same as the sandstone which forms the capping of the ridge E. of Thorpe and of the isolated hillock between the Car Dyke and the River Devon.

Though from the indistinctive character of the strata the prolongation of the Cotham Grange fault cannot be definitely proved to the westward of the alluvium of the Devon, it is suggestive to find that a strong spring of water issues from the marls near Elton, 1,200 yds. N.W. of Stoke Field Farm, approximately on the line of the fault if continued ; and also that a little farther north the steep bluff of the Trent Hills ends abruptly on the same line, giving place to an alluvial flat.

The most northerly of the gypsum quarries at Newark is that of Messrs.

1 'The Geology of the S.W. Part of Lincolnshire,' etc. (*Mem. Geol. Surv.*), 1885, p. 148.

Cafferata & Co., at the foot of Beacon Hill. The section visible here in 1905 was as follows :—

	Ft.	In.
Mixed gypsum and blue marl - - - - 3 to	4	0
Red marl with nodules of gypsum connected by fibrous bands - - - - - - - - -	3	0
Red marl - - - - - - - - - -	4	0
Gypsum ("*top white rock*") - - - 9 in. to	1	0
Red marl - - - - - - - - - -	1	0
"Cakes" of gypsum in rows ("*riders*") - 9 in. to	1	0
Red marl - - - - - - - - - -	1	6
Gypsum ("*middle white rock*") - - - -	1	0
Red marl - - - - - - - - - -	2	6
Gypsum ("*blue rock*") - - - - 9 in. to	1	0
Red marl - - - - - - - - - -	3	6
Gypsum ("*bottom white rock*") - - - - -	–	9

A trial hole continues the section :—

Red marl with two rows of "cakes" of gypsum - -	4	6
Gypsum ("*blue rock*") - - - - - - -	1	0
Red marl - - - - - - - - - -	2	0
Gypsum - - - - - - - - - -	touched	
Total, about	31	9

In a disused gypsum pit at Beacon Hill, apparently the one recorded in a previous Memoir ("*S.W. part of Lincolnshire*," p. 18), the junction of the Keuper Marl with the Rhætics is exposed, but this section is not now very clear. The junction is, however, well seen in a brickyard S. of the high road at Beacon Hill, the details of which are given subsequently (p. 55).

The next section occurs 2 miles farther S. at the Bowbridge Works of the Vale of Belvoir and Newark Plaster Co. The quarry at this place shows the following section, kindly supplied by Mr. Almond :—

	Ft.	In.
Soil [Alluvium] - - - - - - - - -	3	0
Red marl - - - - - - - - - -	7	0
Mixed red and blue marl - - - - - -	7	0
Gypsum ("*top bed stone*") - - - - - -	5	0
Blue marl with cakes of red gypsum - - - -	5	0
Marl with fewer cakes of gypsum - - - -	11	0
Gypsum ("*grey rock*") - - - - - -	3	0
Stone and marl - - - - - - - - -	3	0
Red marl - - - - - - - - - -	7	0
Gypsum - - - - - - - - - -	–	9
Red marl - - - - - - - - - -	2	0
Gypsum - - - - - - - - - -	–	9
Red marl - - - - - - - - - -	2	0
Gypsum - - - - - - - - - -	1	0
Red marl - - - - - - - - - -	3	4
Total, about	61	0

The "3 ft. stone and marl" is believed to correspond to the top bed in the Beacon Hill section.

The section at Messrs. Cafferata's quarry at Hawton, a few hundred yards from the Bowbridge quarry, is similar to the above, but it shows a bed of gypsum one foot thick beneath the bottom marl of that section. In the previous Memoir already referred to the details of a section exposed over 25 years ago at Robinson's pits in Bowbridge Lane is given, which, while essentially similar to the above, differs in some particulars and serves to show the degree of variability of the deposits.

The Tea-green Marl is not more than 18 ft. thick at Beacon Hill. When traced eastwards it is carried down the hillside by the dip until it dis-

appears under superficial deposits near the road from Balderton to Coddington. It does not reappear at the surface until Cotham is reached, and here again is soon overlain by alluvium, its next emergence being S. of the Staunton Grange fault. R. L. S.

Rhætic.[1]

GENERAL ACCOUNT.

Although the Rhætic beds crop out in a very decided escarpment which is continuous and easily traced throughout the greater part of their course, there is at present only one clear section in which they are exposed. We have therefore been able to glean very little new information regarding the series, and are compelled to depend largely upon the descriptions of previous writers, who had the opportunity of examining the sections, now practically obliterated, in the several railway cuttings which have been excavated across the escarpment in this district.

As previously mentioned, in the classification originally adopted the Rhætic Series was held to include the belt of "Tea-green Marl" which is now regarded as forming the uppermost portion of the Keuper Marl (see p. 41); and as this Tea-green Marl passes insensibly into the underlying red marls, the Rhætic beds were supposed to be strictly conformable to the Keuper. But it is now recognised that the Rhætic Series begins with the overlying black "*Avicula-contorta* shales"; and between these shales and the marl there is everywhere in this district a sharp line of division.[2] Whether this division marks an actual unconformity is, however, somewhat doubtful, for although traces of slight erosion have been noticed in places beneath the black shales, there is no evidence of noteworthy denudation of the Keuper beneath the base of the Rhætic, nor of any perceptible difference of dip between the two formations. It has, indeed, been stated[3] by Messrs. A. J. Jukes-Browne and W. H. Dalton that the Rhætic "is separated from the Keuper Marls by a marked unconformity," but so far as the district under consideration is concerned, this statement finds no positive verification.

The following description of the Rhætic Series is in part quoted from the Memoir just referred to[4]:—"It consists of two distinct divisions, the *Avicula-contorta* shales and the White Lias. The *Avicula-contorta* beds lie with a clear line of erosion on the Keuper Marls," and "consist of finely laminated black shales, with a few thin bands of sandstone, and a 'bone bed' at or near the base. These are conformably followed by the White Lias series—thick bedded, light-coloured marls, with

[1] By W. B. Wright and R. L. Sherlock.

[2] E. Wilson, 'The Rhætics of Nottinghamshire.' *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 451.

[3] 'The Geology of the South-west Part of Lincolnshire,' etc. (*Mem. Geol. Surv.*), 1885, p. 19.

[4] *Supra. cit.*, p. 19.

yellowish, fine-grained limestones in irregular nodular bands." The entire series is about 33 ft. thick. Its dip is found, by calculation from the well-sections and other data, to be 85 ft. per mile toward east-south-east, but is liable to considerable local variation.

The only places on the map where definite information regarding the relations of the Rhætic to the Keuper is forthcoming are at Newark and at Barnstone. At Barnstone, according to the late E. Wilson, "the Upper Keuper red gypsiferous marls, with the usual 'Tea-green marls' above, were overlain, with the usual sharp line of division, by the *Avicula-contorta* shales."[1] The section at Newark is described below.

The "bone-bed" which, according to Wilson, occurs at Barnstone 1 ft. 6 in. above the base of the Rhætic, has also been observed by Mr. W. J. Harrison in the cutting west of Elton Station (see p. 57). It has not been proved at Kilvington, and is known to be absent in the cutting at Cotham, and in the Newark section.

The following fossils from the Rhætic of the district are represented in the collections of the Palæontological Department of the Geological Survey at the Jermyn Street Museum. Some of these were obtained during the recent survey, and others previously. Further species are recorded by E. Wilson in the paper referred to above.

Myophoria? cloacina (*Moore*)	Newark.
Protocardia rhætica (*Merian*)	„ and Elton.
Pteria contorta (*Portl*) [Avicula *Auctt.*]	Newark.
"Pullastra" arenicola *Strickl.*	„

Lamellibranchs of doubtful generic position resembling:—

Axinus depressus (*Moore*)	Newark.
Isodonta præcursor (*Schloth*)	„

Also

Fish (fragments)	„ and Elton.
Wood	Newark.

DETAILS.

The Newark exposure of the Rhætic Beds previously referred to occurs at the top of an old gypsum quarry at Beacon Hill, on the S. side of the Sleaford Road. At the time of the previous survey, beds were seen higher in the series than any now visible.[2] As our re-measurement of the section still exposed agrees closely with the record given by Mr. Holloway in the former Memoir, we shall repeat here the details of the whole as given by him. The section was in two portions, as follows:—

"1. Upper section near dilapidated cottage. On the upper side of this hole by the fence fragments of the 'sun-bed' (White Lias), and of the *Ostrea* beds occur in the soil which is almost entirely made up of grey marl.

1 'The Rhætics of Nottinghamshire.' *Quart. Journ. Geol. Soc.*, vol. xxxviii 1882, p. 453.

2 'Geology of the S.W. Part of Lincolnshire.' (*Mem. Geol. Surv.*), 1885, p. 21.

(The subsequent cutting back of the section has shown 3 ft. of grey shales, with the base of the White Lias just visible above them.)"

	Ft.	In.
"Soil and grey marl, containing towards the base sandy micaceous bands, showing ripple mark distinctly	5	7
Dark grey sandy micaceous marls weathering into ferruginous yellow and red (passing down into next)	2	6
Darker and much more shaly marls, weathering very ferruginous, but fracture of unweathered portion black variegated with grey. At base a thin band of micaceous sand	1	4
Black shales, sometimes sandy, with very thin white sandy band, at base only a line thick	0	5
Black shales weathering rusty with impressions of bivalves	0	3
Black shales as above, but without fossils	1	1
" " with *Avicula contorta*	0	6
" " seen for	2	0
	13	8

"2. Second section intermediate between the Red Marl workings and the section above described.

	Ft.	In.
"Soil	2	3
Brown and grey shales	0	9
Black paper shales, with *Avicula contorta*	1	6
Slate coloured grey and brown shales with a thin sandy line at the base	0	10
Sandy micaceous slate coloured shale, weathering whitish	0	2
Black sandy shales, weathering rusty	0	9
Thin band of pinkish-white sandstone from ½ in. to	0	1
Slate-coloured shale, weathering whitish	0	2½
White, yellowish, and pink sandstone, very micaceous	0	1½
Black and slate-coloured micaceous shales	0	7
Brownish, grey and black shales, with thin sandy lines	2	2
White sandstone with shells	0	1
Black shales, weathering rusty, fossiliferous in bands	2	1
Band of sandstone with shells	0	1
Black shales becoming harder towards the bottom	5	6
Thin band of sandstone	0	1
Black shales	1	3
Grey marl at bottom	—	
	18	6"

In our re-examination of this lower section in 1905, a large piece of lignite, representing either the branch or trunk of a tree, was found at 7½ ft. above the Tea-green Marl ("grey marl at bottom"). At the height of 11 ft. above the Tea-green Marl the beds contain nodules with a core of rottenstone in which are the casts of bivalve shells; and this is the most fossiliferous portion of the section, but even here fossils are not very numerous. A few fish scales and fragments of bone occur in the black paper-shales, but the basal bone-bed is absent. The junction of the Rhætic with the Tea-green Marl is quite abrupt, without, however, showing recognisable unconformity. The black shales are often stained with rusty patches, and numerous minute radiating groups of crystals of gypsum occur between the laminæ, doubtless resulting from the decomposition of pyrites or marcasite.

The top of the Rhætic Series is described as follows in the previous Memoir :—

"A Lias Quarry on the Coddington road was deepened by Messrs. Holloway & Woodward, and at the base of the Lower Lias series there was exposed a hard compact homogeneous limestone, in texture not unlike the 'Sun-bed' of the West of England. This bed was much waterworn, owing to the action of the water sustained by the clayey beds beneath it." [1]

The position of the Rhætic outcrop in its prolongation south of Newark was confirmed by two wells ; one of these, opposite Cotham Field, showed about 10 ft. of black sandy shale, underlying 8 ft. of "silt," probably rain-wash ; and the second, about 52 ft. deep, in the farmyard at Cotham Grange, penetrated a few feet of Lias and the whole of the Rhætic, ending in the Tea-green marl.

R. L. S.

South of Staunton Grange the Rhætic beds occupy the face of a well-marked and tolerably regular escarpment until they finally leave the area of the map near Cotgrave. At Staunton Hall the escarpment is trenched by the valley of the Devon, which here takes a sharp turn and breaks through the hill in a narrow valley.

The railway cutting at Kilvington is now obscured, but Wilson noted here the following series :—

		Ft.	In.
"Soil and thin-bedded Lias limestones and shales		3	0
White Lias.	Shales, weathered yellow	0	11
	Nodular band	0	3
	Shales, weathered yellow	1	8
	Nodular band	0	4
	Shales, weathered yellow	4	0
	" " blue	9	0
Black paper shales.			

A large nodule from the upper part of the White Lias was crowded with *Estheria minuta*, var. *Brodiana*." [2]

At Alverton the escarpment turns abruptly to the north-west and continues this course to Flawborough, where it resumes its normal south-westerly direction. The reason for this striking change of course is not apparent, for there does not appear to be any fault here. In Flawborough, on the S. side of the road, 150 yds. E. of the church, the basal limestones of the Lias, seen in the bank of a pond, appear to roll over towards the north-east, dipping in the direction of the escarpment.

The black paper shales and overlying grey marls are still visible in some small exposures in the overgrown cutting W. of Elton Station. "Here Mr. W. J. Harrison found a bone bed resting, as at Leicester, on the light grey Keuper Marls, and overlaid by black paper shales with the usual fossils." [2]

Orston Spa is a chalybeate spring, due, probably, to a pyritous bed in the shales (see p. 96).

Blackberry Hill is an outlier of the Rhætic Shales and White Lias caused by the Elton fault, which has a downthrow to the north. The main outcrop of the Rhætic is displaced at Elton by this fault and thrown back nearly ½ mile to the S.E. From here it can be traced S.W. by Sutton and Granby to Barnstone, its escarpment being trenched by the valley of the Whipling between the two places last mentioned.

The section in the railway cutting at Barnstone was examined when freshly

1 'Geology of the S.W. Part of Lincolnshire' (*Mem. Geol. Surv.*), 1885, p. 21.
2 *Ibid.*, p. 20.

exposed by Wilson, whose results are given as follows in he previous Memoir[1] :—

		Ft.	In.
Lias.	Thin-bedded blue limestone and brown clays, at the base a compact or concretionary bed of limestone, from 3 to 7 in. thick. - -	10	0
White Lias.	Layer of limestone nodules - - - -	0	6
	Thick-bedded, earthy, dark blue shales, with frequent nodules of limestone - - -	3	0
	Similar shales with occasional nodules near the centre - - - - - about	15	0
Avicula-contorta Beds.	"Paper shales" (*Avicula contorta* zone), with thin variable yellow sandstones in the upper part - - - - - - - - - -	13	4
	Bone bed, with the usual fish remains - -	0	2
	Paper shales sharply divided from - -	1	6
Keuper.	Hard, light blue marls [Tea-green Marls] -	12	0
	Red Keuper Marls, with thin gypsum bands.		

Wilson states that the "Bone-bed" at a few feet deep is intensely hard and pyritic, though quite soft and friable at the outcrop.[2]

On the S.W. side of Barnstone the Rhætic scarp passes across the southern boundary of the map, but swings back again at Fern Covert,[3] about a mile farther westward. In the north-westerly face of Fern Hill, at the place marked *Spring Spinney* on the 6-in. map, a small spring issues from the lower beds of the Rhætic ; and its position on a salient portion of the escarpment is evidence that the beds here form a synclinal trough running N.W. and S.E. An outlier of the "paper-shales" occurs on Hoe Hill, north of Cropwell Bishop.

Half-way between Cropwell Bishop and Cotgrave, near where the Foss Way ascends the Rhætic escarpment, some pits in the basal beds of the Lias show that the dip is here much steeper than usual, being not less than 5 deg. to the south. The band of fine-grained limestone, which is taken as the topmost bed of the Rhætic, here attains a thickness of 18 in. or more, and is quarried for road metal at a little distance south of the limits of the map. W. B. W.

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1 *Supra cit.*, p. 20.

2 'The Rhætics of Nottinghamshire.' *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 455.

3 *Langar Lane Covert* of the new map.

CHAPTER V.

LOWER LIAS.[1]

GENERAL ACCOUNT.

The Lower Lias that occurs along the eastern margin of the map is the outer fringe of the broad outcrop of this formation, which extends eastward for several miles beyond the map. The whole breadth of the outcrop lay within Sheet 70 of the Old Series map and was described in the Memoir accompanying the sheet.[2] The account given in that Memoir of the lower portion of the formation being based on the examination of a wider area than has fallen within the scope of our recent work will be followed and in part repeated in the present description.

Lithologically, the Lower Lias of the area with which we have to deal may be separated into the following subdivisions, in descending order, approximately agreeing with the classification adopted in the previous Memoir:—

D. Clays above the Ferruginous Limestone.
C. The Ferruginous Limestone Beds.
B. Clays below the Ferruginous Limestone.
A. The Hydraulic Limestone Series.

The relations of these subdivisions to the palæontological zones based on the occurrence of successive forms of ammonites in the formation is as follows:—The lowest division (A) corresponds very closely with the zone of *Psiloceras planorbis*. The second (B) represents the combined zones of *Schlotheimia angulata* and *Coroniceras bucklandi*, which are not separately recognisable in this district. The third (C) forms the lower part only of the zone of *Arnioceras semicostatum*, which extends upward into the overlying clays (D), and includes the greater part of these clays that fall within the present map, so that the next higher zone—that of *Oxynoticeras oxynotum*—can occupy only a small triangular space in the south-east corner of the sheet.

The leading characters of the subdivisions will now be stated, and afterwards the local details of their outcrop will be described. The succession is illustrated in the section, Fig. 5.

(A) *Hydraulic Limestone Series.*—These beds follow conformably on the highest strata of the Rhætic Series, and are best exposed in the quarries of the Barnstone Cement Works. The lowest portion consists of grey or blue-grey laminated shales interbedded with fine-grained shaly limestone of a blue-grey colour, but weathering nearly white. Fossils are occasionally plentiful in these beds, and include the remains of saurians, fish, crustaceans, plants, and sometimes insects.

[1] By W. B. Wright, with contributions by R. L. Sherlock and G. W. Lamplugh.

[2] 'The Geology of the South-West Part of Lincolnshire,' etc., by A. J. Jukes-Browne and W. H. Dalton.

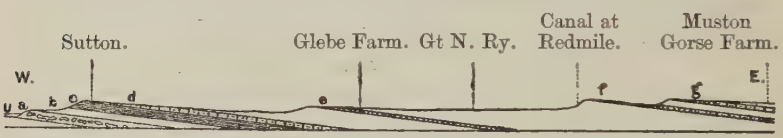
Above these beds are others of similar type, in which the limestone bands are of a rather coarser grain and sometimes of a shelly structure, which are characterised by the presence of *Psiloceras planorbis*, in a crushed condition. A small dwarfed oyster is common, and remains of saurians are sometimes found.

The portion of a reptilian skeleton (*Ichthyosaurus*), probably from these beds, found at Elton and described by Dr. W. Stukeley in 1719,[1] is of classical interest, as it is said to be the first recognition of fossil reptilian remains in Britain.

The thickness of the whole Limestone Series does not appear to be more than 20 ft. near Barnstone, but it appears to thicken northward and may be about 40 ft. thick between Cotham and Coddington. Its outcrop occupies a belt of land about ¾ mile wide, sloping gently towards the Vale of Belvoir. The limestones are everywhere exposed in the ditches and cattle ponds along this dip slope.

Fig. 5.—Section from Sutton to Muston Gorse, showing the Relative Position of some of the Limestone Bands in the Lower Lias.

Horizontal scale, 1 *in.* = 1 *mile*. *Vertical scale*, × 5.



v.	Alluvium of Moor Dike.	d.	The Hydraulic Limestones.
g.	Bands of limestone.	c.	Rhætic Beds.
f.	The Ferruginous limestone belt.	b.	Tea-green Marl } Keuper.
e.	Three or four thin bands of limestone.	a.	Gypsiferous Marls }

(B) *Clays below the Ferruginous Limestone.*—This subdivision consists of dark blue clays with occasional bands of septarian nodules and thin limestones, sometimes containing fossils, those found in the clay being often mineralised by pyrites. About one-third of the way up in the subdivision there is a conspicuous belt (*e* of Fig. 5) consisting of three or four beds of limestone from 2 to 6 in. in thickness, separated by clays and shales, which forms a fairly prominent escarpment, running from Jericho Lodge east of Granby to Three Shire Bush, where it is cut out by the Staunton fault.

The upper part of the subdivision contains numbers of gryphæas which increase in abundance towards the top of the zone, and reach their maximum just below, or in the bottom of, the overlying ferruginous limestone, at which horizon they are ploughed up by thousands in many of the fields.

(C) *The Ferruginous Limestone Beds.*—These beds represent the thinning out, or replacement by clays, of a belt which becomes more conspicuous farther northward and attains its

[1] 'An account of the Impression of the almost entire Sceleton of a large animal in a very hard stone, lately presented to the Royal Society, from Nottinghamshire.' *Phil. Trans.*, vol. xxx, 1719, pp. 963-8, with plate.

greatest importance in North Lincolnshire, where, in the Frodingham district, it has a maximum thickness of 27 ft. and includes valuable ironstones that are worked on a large scale.

In their outcrop within the map the beds include some impersistent layers of ferruginous limestone not more than 2 or 3 ft. in thickness, which are nowhere well exposed, but form a red rubbly soil on the dip-slope of a fairly prominent escarpment in the Vale of Belvoir. These rusty beds are sometimes absent from the actual escarpment, and in some cases occur so far down the dip-slope as to raise the suspicion that they are not mainly responsible for the feature and that there may be some strong beds of limestone just below the ferruginous zone which we have been unable to trace. The rock-bands of this horizon abound in fossils, amongst which *Gryphæa arcuata* and *Cardinia listeri* are especially abundant.

(D) *Clays above the Ferruginous Limestone.*—The limited area of these clays in the present map presents comparatively unimportant features. Some rather strong limestone beds which occur in their lower part form a small escarpment about ½ mile S.E. of that which marks the course of the ferruginous limestone. These limestones, shown as the fourth limestone belt in the accompanying section (*g* in Fig. 5) appear to belong, like the ferruginous limestone below, to the zone of *Arnioceras semicostatum*. Another small escarpment further to the south-east, which crosses Muston Gorse in a parallel direction, is probably caused by the continuation of a band of sandy limestone lying approximately at the top of the *semicostatus* zone, which thickens and becomes more conspicuous when traced south-westward into the next sheet.

W. B. W.

DETAILS.

In the north-east corner of the map the Hydraulic Limestone subdivision caps the prominent escarpment of Beacon Hill, which rises about 100 ft. above the Keuper flat. Many quarries, now no longer worked, occur on the hill; and one of these, ¼ mile W. of "The Moat," still shows a section fairly typical of the series.

The details of this section are as follows:—

	Ft.	In.
Clay soil	1	6
Limestone, broken and weathered	0	6
Shale, weathered brown	2	0
Limestone in two layers	0	9
Sandy shale	2	6
Limestone in two layers	1	6
Sandy shale	3	0
Limestone with *Ostrea*	1	9
Sandy shale	1	9
Limestone with a parting of shale; *Ostrea* very abundant	1	9
Sandy shale	2	0
Limestone	1	0
Sandy shale	3	0
Limestone	1	0
Sandy shale, to bottom of quarry	2	0
About	26	0

The following fossils have been obtained from this quarry[1]:—Echinoid spine; *Cardium?; Inoceramus* sp.: *Modiola minima*, J. Sow.; *Ostrea liassica?* Strickl.; *Psiloceras?; Ichthyosaurus* (tooth fragment); and a fish scale.

South-east of Beacon Hill the escarpment of the Rhætic and Lias is masked by the high-level gravels of the Trent, but it emerges again at Balderton as a much reduced though still prominent feature. On the crest of this feature the limestones may often be seen in the ditches under about 2 ft. of soil, and there are traces of small quarries in them on the Great Northern main line, at Balderfield, and by the roadside, ¼ mile S.E. of Frog Hole; and again further south where the Lias rises from beneath the alluvium of the Shire Dyke. The following account of the exposures in the last-mentioned tract is given in the previous Memoir:—

"Between Moor Drain and East Cotham Hill [Bennington Lodge Farm on the new map] many small quarries have been opened on both sides of Moor Lane, and as much of the stone as could be extracted, without trouble from water, having been raised, they have been ploughed over or left as ponds.

"In such as are still open the beds may be seen lying in a slight synclinal, which trends to a little east of north. The lower beds on either side (S. of East Cotham Hill and a quarter of a mile west of Moor Drain, where it crosses the lane) are blue-grey, fine, close-grained limestones, separated by bands of shale. Over these in the centre of the synclinal is a series of shelly ragstones, less purely calcareous. Both form part of the *Ammonites planorbis* zone, and in 1880 both were well exposed in a pit half a mile S.E. of East Cotham Hill. The section here . . . exhibits no less than eight different beds of limestone and to seven of these the workmen have given special names. The three lowermost make the best lime, those above being of inferior quality. The beds have a local dip of about 2 deg. to the south."

It is unnecessary to reprint the details of the section, as they bear a general resemblance to those of the Beacon Hill section given above; the total depth is 12 ft. 9 in., and the limestone bands vary from 3 in. to a foot in thickness with intercalations of shale of similar thickness. The lowest bed seen is black shale, 1½ ft. thick, and the workmen state that below this black shale there is a white clay.

"In the seventh limestone [counting upwards], called 'the Brush,' Saurian remains are abundant, together with a small species of oyster (*O. irregularis*) which is everywhere frequent in the upper part of the series. The bones obtained from the workmen at this pit included a portion of the jaw of *Ichthyosaurus tenuirostris*, together with vertebræ, an ulna, and a humerus with radius, probably belonging to the same species of *Ichthyosaurus*."[2]

The only pit now being worked lies a mile S.E. of Bennington Lodge Farm (East Cotham Hill of the former map).

The cuttings on the Great Northern Railway between Cotham and Staunton, now obscured, were examined when they were fresh by E. Wilson, who furnished the full details regarding them given in the previous Memoir.

In the cutting near Staunton Grange the basement beds of the Lias were faulted against the Triassic Marls, and dipped steeply to the north.

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[1] Identified and preserved in the Palæont. Department of the Survey.
[2] Memoir, *suprà cit.*, pp. 26-7.

The section measured here by Wilson may be condensed as follows :—

	Ft.	In.
Marls with occasional bands of nodules	13	0
Two bands of limestone, with a parting of marl	1	0
Marls	1	1
Sandy seam	–	4
Limestone, with a parting of marl	–	8
Sandy seam	0	3
Marls, with a 10-in. band of limestone	2	11
Calcareous sandstone	0	2
Thin alternations of marls and limestone	2	1
Shale	1	0
Nodular limestone	0	4
Shale	3	0
Limestone, earthy 2 in., compact blue, 7 in.	0	9
	26	7

"The dip is northward, about 10°, and the upper beds of the above section do not extend to the fault within the cutting. About 240 yards north of the fault the northerly dip is exchanged for a southerly one of 2° to 3°, which appears to be persistent to beyond Cotham Station. . . ." "The cutting at Cotham Station shows a few feet of the lower part of the Lias over the Rhætic Marls. Some fair specimens of *Ammonites planorbis* and other fossils have been found in the limestones. The beds here dip slightly to the south, but roll over in the hollow northward of the station, and in the next cutting dip to the north at angles varying from 2° to 16°." The section measured by Wilson, which it will be unnecessary to reprint in detail,[1] showed 19 ft. 6 in. of limestone and shale in thin alternations, the limestone bands varying from 3 in. to 1 ft in thickness, and aggregating to 6 ft. 7 in. The Rhætic beds were exposed at the base of this section.

R. L. S.

North of Staunton the Hydraulic Limestones are cut out by a fault, and between this fault and the county boundary the soil is quite free from limestone rubble. South-west of the farm called Outhorpe, however, and capping the escarpment along the foot of which the Staunton Grange and Long Bennington fault lies, the soil contains limestone fragments. From the relation of the limestone thus indicated to the outlier of the Ferruginous Limestone on Folly Hill, we are inclined to regard it as belonging to the second limestone belt (see Fig. 5) which runs from Jericho Lodge to Normanton, and not to the Hydraulic Series as previously supposed.

Only the lower 3 ft. of the Hydraulic Limestones and shales are recorded by Wilson as having been exposed in the cutting between Kilvington and Alverton (see p. 57).

The small outliers of Lias shown capping hills to the north-east of Orston are inserted on the general evidence only, no sections having been seen in them.

The cutting west of Elton station is quite overgrown, and we have no information respecting it. In the village of Elton, about 150 yds. south of the church, a drain for a new house revealed a section in limestone and clays, 4 ft. in depth, overlying the fine-grained nodular limestone, which we consider to mark the top of the Rhætic. An extensive area about ½ mile north-east of Elton has been formerly excavated for limestone.

The upper part of the Hydraulic Limestones can be seen in a pit ¼ mile S.E. of Granby Church. The beds show the usual alternations of limestone and shale, of which the details, to a depth of 8 ft. 6 in., are given in the previous Memoir.

The best section of the Hydraulic Limestones in the district is that exposed in the quarries of the Blue Lias Lime and Cement Company at

1 See p. 27 of Memoir, *supra cit.*

Barnstone a little over ¼ mile S. of the Church. The following section was measured by Mr. H. B. Woodward [1] at this place :—

	Ft.	In.
Contorted clayey soil and drift	2	0
Pale argillaceous limestones (two), and clay	2	0
Racy clay	2	4
Two or three thick and thin beds of limestone	1	8
Grey shale	2	6
Best stone ; pale and banded earthy limestone	0	9
Shale	1	1
Two or three beds of limestone	1	4
Shale	1	7
Limestones, wavy-banded and pyritic	1	6
Shale	1	6
Grey argillaceous limestone ("Bottom floor")	0	8
	18	11

The beds dip to the S.E. at an angle of about 2 deg. Good specimens of fossil fish are occasionally obtained from this quarry, and also the remains of *Ichthyosaurus* and *Plesiosaurus*. The zonal ammonite, *Psiloceras planorbis* is rare and ill-preserved. Among the fossils obtained here during the recent survey are the following [2] :—*Arietites* sp. ; *Nautilus* sp. ; *Lima gigantea* (J. Sow.) ; *Lima succincta* Schloth. ; *Modiola minima* J. Sow. ; *Ostrea irregularis* Münst. ; *Ostrea liassica* Strickl. ; *Pleuromya* cf. *crowcombeia* Tate.

Respecting the clays which overlie the Hydraulic Limestones, very little detailed information is obtainable in this district, there being few sections in them. The limestone belt which we have described above as occurring about a third of the way up in these beds is, however, exposed in one or two places.

The tip-heap of a well sunk at Normanton to a reported depth of 40 ft. in the slope of the escarpment of these limestone beds was found to consist of dark blue-grey clays and shales, with blocks of limestone from a band 6 in. in thickness. Among the fossils collected from this tip are the following [2] :—*Schlotheimia angulata* (Schloth.) and an arietite ammonite ; *Astarte camertonensis* Moore ; *Cardinia listeri* (J. Sow.) ; *Lima hettangiensis* Terq. ; *Modiola minima* J. Sow. ; *Nuculana* cf. *subovalis* Münst. ; *Ostrea irregularis* Münst. ; *Ostrea liassica* Strickl. ; *Protocardia* sp. ; *Unicardium* sp. ; *Pentacrinus angulatus* Oppel.

The presence of the first-mentioned fossil of this list confirms the opinion that these beds belong to the second zone of the Lower Lias—the zone of *Schlotheimia angulata ;* but, in the absence of continuous sections or special characters, it is impossible in this district to separate the zone from the next in upward succession—the zone of *Coroniceras bucklandi.*

About 300 yds. N. of the intersection of the main railway lines at Bottesford Junction, one or two of the limestone beds are seen to cross the stream on the E. side of the railway, and they are all exposed in the Winter Beck N.E. of Highfield House. A little higher up this latter stream, close to where it first coincides with the county boundary, some shales thrown out of a hole yielded bones, presumably saurian. A "stone floor" was reported in a waterhole beneath 9 ft. of stiff blue Lias clay, 200 yds. N.W. of The Lodge, and a bed of limestone, 6 in. thick, is exposed in two waterholes S. of the same house.

Passing southward along the same belt we find four beds of compact limestone, varying in thickness from 3 in. to a foot, exposed in the bed of the little stream known as the Grimmer, and slight exposures of this belt also occur at the side of the road leading from Sutton to Redmile, ¼ mile N.W. of Glebe Farm, and in some waterholes S.W. of Jericho Lodge.

Some beds of limestone which probably belong to this zone appear to outcrop on the ridge S. of the Long Bennington and Staunton Grange

[1] 'The Jurassic Rocks of Britain,' vol. iii, (*Mem. Geol. Surv.*), 1893, p. 172.
[2] Identified and preserved in the Palæont. Department of the Survey.

Fault, E. of the farm called Outhorpe, but no exposure of them has been seen.

The remainder of the clayey subdivision up to the Ferruginous Limestone consists of clays and shales with a few minor beds of limestone, none of which are sufficiently strong to cause a perceptible feature. The tip-heap of a well in *Barkestone Lane*, a mile S.W. of Bottesford Wharf, consisted of blue clays and shales, with some small fragments of limestone. *Gryphæa arcuata* Lam.; *Ostrea* sp.; *Pecten* sp.; and an arietite-ammonite were collected from it.[1]

A brickyard at Bottesford, ¼ mile N.W. of the Church, shows 5 ft. of clays but appears to have been deeper formerly, the section as described in the former Memoir (p. 28) consisting of 5 ft. of soil and gravel, overlying 6 ft. of Lias clay with two thin bands of limestone. Another brickyard ½ mile W.S.W. of Bottesford, in which "clay full of Gryphæas" was recorded, is now quite overgrown. A band of limestone is exposed in the bed of the Devon close to Easthorpe Mill.

In the clays about 30 or 40 ft. below the top of the subdivision there occurs a thin band of fine-grained nodular limestone with marked characters, which generally contains *Modiola minima* in abundance. Though not seen in open section, this limestone is easily traceable by the fragments which occur in the fields, and it can be followed from the eastern limits of the map around the slopes of Beacon Hill, N. of Bottesford, to about a mile W. of this village, where it sinks beneath the alluvium of the Devon. Its course again becomes traceable about ¾ mile W. of Muston and extends round the northern base of Toston Hill; while farther southward its fragments occur at intervals along the slopes below the Grantham Canal. A slightly nodular limestone bed 4 in. thick is visible in the cutting S.W. of Redmile Station, but differs somewhat in character from that just described (see also previous Memoir, p. 28).

Large fossiliferous concretions of hard sandy limestone are mentioned in the previous Memoir as occurring "in the side of the brook which flows between Barkston and Redmile, at a spot about ½ mile S.W. of Redmile Church," and the following fossils are recorded from this spot:—*Gryphæa incurva; Pecten* sp.; *Avicula* sp.; *Lima duplicata; Pinna spathulata; Modiola scalprum.*

With the scanty evidence available, it is not possible in this district to determine what proportion of the clays with occasional limestones above described should be assigned respectively to the *angulata* zone and to the *bucklandi* zone; and indeed even where the Lower Lias can be studied in continuous coast-sections the boundary between these zones is often indefinite.[2] The top of these clays is, however, regarded as the upward limit of the *bucklandi* zone; and the Ferruginous Limestone subdivision which comes next in upward succession forms the lower part of the zone of *Arnioceras semicostatum.*

The most northerly occurrence of these Ferruginous Limestone beds is on Folly Hill, a mile E. of Staunton, where an outlier of the characteristic ferruginous soil with limestone fragments and gryphæas caps the hill. This outlier is on the downthrow side of the Three Shire Bush Fault.

The same beds re-appear as a capping to the high ground N. of Muston where they are exposed in the ditches; and a bed 18 in. thick is well exposed in a waterhole 200 yds. N. of where the railway leaves the map.

The rusty-red soil is next seen on the hill, ½ to ¾ mile W. of Muston Church, and there is an outlier of it on Toston Hill. The ferruginous soil is discontinuous and patchy in this neighbourhood, and even the limestone beds cannot be everywhere traced. They are exposed in a stream 700 yds. E.N.E. of Middlestile Bridge; and ¼ mile above where the Easthorpe Road crosses the stream the following section was seen:—

	Ft.	In.
Ochreous clay greyish at bottom, containing *Gryphæa, Lima,* &c. - - - - - - - -	1	6
Dirty limestone composed largely of *Gryphæa* - -	0	6
Grey clay stained red in places, with comparatively few fossils - - - - - - - - - -	2	0

[1] Identified and preserved in the Palæont. Department of the Survey.

[2] 'The Jurassic Rocks of Britain,' vol. iii, by H. B. Woodward (*Mem. Geol. Surv.*), 1893, p. 60 *et seq.*

The *gryphæa*-limestone crosses the bed of the stream some 20 yds. above this section; and, a few yards beyond, a thick bed of ferruginous and clayey limestone with abundant fossils is exposed in the banks. From this bed the following were collected[1]: An arietite ammonite; *Cardinia concinna* (J. Sow.); *Cardinia listeri* (J. Sow.) var. hybrida J. Sow.; *Hippopodium ponderosum* J. Sow.; *Lima* sp.; *Ostrea* sp.; *Pecten* sp.; *Chemnitzia* sp.; *Discohelix* sp.

From this exposure the ferruginous belt can be traced W. and S.W. past Hill Farm, where it rises to the crest of the feature, as far as Redmile. About 100 yards S.E. of the Rectory at Redmile one of the limestone beds with abundant *Gryphæa* is exposed in a waterhole, and it is mentioned in the previous Memoir (p. 30) that the ferruginous rock was seen in the foundations of houses near the church; it appears to have been dug in old pits in a field one furlong to the S.S.W.; but its further prolongation in this direction is very indefinite.

As already mentioned, considerable thickness of the clays or shales which overlie the Ferruginous Limestone appear also to belong to the *semicostatus*-zone, and include a well-defined belt of limestones, which forms a low feature traceable across the S.E. corner of the map for a distance of about 3 miles. One of the limestones of this horizon, a compact bed 5 in. thick, is exposed in the Devon S.E. of Muston, 100 yds. above the railway bridge. Another outcrop of the belt occurs in the Muston Gorse Stream, from 450 to 700 yds. N. of Muston Gorse Wharf, showing three beds of limestone, which measure respectively, in upward order, 14 in., 7 in., and 4 in. in thickness. These limestones are compact and homogeneous, and the uppermost is very fossiliferous, abounding especially in Pectens. The following fossils are collected from this bed[1]:—*Cardinia listeri* (J. Sow.); *Gryphæa cymbium* Lam.; *Lima pectinoides?* (J. Sow.); *Lima* sp.; *Modiola scalprum?* (J. Sow.); *Ostrea* sp.; *Pecten* of. *thiollieri* Mart.; *Pecten* sp.

Higher up the stream, grey clays and shales are seen exposed. Above this horizon *Gryphæa* becomes comparatively rare.

W. B. W.

[1] Identified and preserved in the Palæont. Department of the Survey.

CHAPTER VI.

GLACIAL DEPOSITS.[1]

GENERAL ACCOUNT.

The general characters of the glacial deposits of the district have already been indicated in the first chapter of this Memoir (p. 7), but owing to their relative scantiness, the somewhat indefinite patches that do occur deserve particular attention.

In Annesley Park, two miles beyond the north-western corner of the map, there occurs a patch of gravelly drift in which a few boulders transported from the Lake District have been detected; and other phenomena farther westward seem also to indicate that the margin of the glacial stream from the north-west at one time impinged upon the district. The Annesley drift lies at about 600 ft. above sea level; and it is possible that some patches of similar gravelly material which form here and there a thin capping to the hills of Bunter, in the north-western part of the present map, reaching a maximum elevation of 400 ft. in Bestwood Park, are the product of the same ice-sheet, either by direct transport or by the distributing effect of the flood-waters issuing from it. This drift appears to follow the eastern rim of the Leen Valley, and also occurs in places on lower hills within the rim.

It is certain that there has been great erosion of the district since this gravelly drift was deposited, and the patches now remaining on the hills are probably only the shreds of the original formation. The diminishing altitude at which these patches are found, as the irregular chain is followed toward the Leen, and southward toward the edge of the Trent Valley, may roughly indicate the gradients of the surface on which they were deposited.

In composition, this gravelly drift always contains a preponderance of pebbles derived from the Bunter, and where it rests directly upon the Bunter Pebble Beds, there is difficulty in distinguishing between the re-arranged drift material and the original formation, and still greater difficulty in distinguishing the post-glacial rain-wash from the drift with which it is often mingled.

Usually, however, the drift contains an occasional pebble or small boulder of Carboniferous sandstone or other erratic, different in character from the pebbles of the Bunter and of larger size.

It is often difficult to decide whether the lower of these gravelly patches, which form ill-defined ledges on the outer slopes of the Leen Valley and elsewhere, should be coloured on the map as "Glacial" or as "Late-glacial Flood-gravels," and the

[1] By G. W. Lamplugh and W. B. Wright, with notes by R. L. Sherlock.

first-mentioned alternative was adopted only because the deposits in question appear to be somewhat older than the gravels of the Trent Valley that are assigned to the "Flood-gravel" stage. In fact, scanty as the superficial deposits of this district are, at one spot or another they probably represent every stage from the period of maximum glaciation to the present day.

It has been suggested by Mr. R. M. Deeley[1] that several distinct periods or phases of glaciation, separated by interglacial episodes, can be distinguished in the drifts of the Trent Basin, and that most of the above-mentioned gravels represent one or another of the interglacial stages. We have been unable, however, in this district, to find satisfactory evidence for the proposed classification, or for the supposed recrudescence of ice-sheets after the deposition of the older valley-gravels. The subject will be further discussed in dealing with these gravels (see p. 73).

On the Keuper Marl Upland east of Nottingham and north of the Trent the 'solid' formation almost invariably occurs immediately beneath the soil or beneath a thin 'rain-wash' of local derivation, so that the area is practically driftless. Where the land is under cultivation, however, it is usually found that an occasional pebble from the Bunter is present in the soil, and in a few places these become fairly numerous. Some, perhaps most, of these may have been artificially introduced in the processes of cultivation (with manure, etc.), as pebbly gravel is much used around the farmsteads and in gateways on this stiff clay-land. But it is possible that there may have been patches of pebbly gravel on the upland in places, which have disappeared or been widely distributed during the general lowering of the surface which has taken place since Glacial times, so that the absence of drift is not absolute proof that the area has lain beyond the limits of glaciation. The presence of an occasional pebble of quartzite in the gravelly detritus forming the base of the alluvium of little streams which descend from the upland, *e.g.*, the Cocker Beck (p. 86), lends some support to the suggestion; and still more to the point is the existence of a small patch of gravel on the crest of the bluff overlooking the Trent at *Colwick Wood*, at 300 ft. above O.D., or 225 ft. above the Trent flat (see p. 71).

With the exception of the gravelly drift of Wilford Hill, described on p. 71, there is hardly any undoubted glacial material in the country south-east of the Trent that lies within the map. Frequently the Keuper Marl and the Lias clay of the low ground carry irregular pockets of stony material, sometimes sandy and sometimes mixed with clay; but it is always doubtful whether this material represents the direct product of glaciation, or whether it is only the rearranged land-wash or stream-wash with which the relics of once-existing glacial deposits have been incorporated. And this doubt has been increased by the result of the survey of the adjoining sheet on the south (Sheet 142),

[1] 'The Pleistocene Succession in the Trent Basin,' *Quart. Journ. Geol. Soc.* vol. xlii, 1886, pp. 470–480.

recently completed; where it is found that the Chalky Boulder-clay—the latest direct product of glaciation recognisable in the district—occupies a well-defined plateau and ends off abruptly at its margin. Here it is evident that the lower ground has suffered great erosion since the boulder-clay was accumulated; and the only drifts remaining upon it are patches here and there of the same nondescript material that occurs in its northern prolongation with which we are now dealing.

This stony accumulation, whatever its origin, has, however, considerable effect upon the character of the soil; and being of some agricultural consequence, requires to be shown on the map. It has therefore been indicated, where thickest, by the 'boulder-clay' colour, which best indicates its lithological character. But it must be understood that the application of the 'boulder-clay' colour here does not necessarily imply that the material is a direct product of the glacial agencies, or equivalent to the Chalky Boulder-clay of the plateau to the south.

G. W. L.

DETAILS.

Patches of gravelly detritus of doubtful age form the summits of small hills on both sides of the Leen Valley between Papplewick and Bulwell, at elevations ranging from 430 ft. to 200 ft. above O.D. The high ground of Bestwood Park at an elevation of slightly over 400 ft. is covered with sandy and gravelly material, which is not confined to the Bunter outcrop but rests in places upon the Keuper Waterstones. The presence of glacial drift at this locality is further indicated by the occurrence of a boulder of andesite, measuring 18 in. by 12 in. by 6 in., which lies 40 yds. within the N.E. corner of the plantation at Violet Hill. Isolated patches of similar gravelly drift occur at about the same elevation for nearly a mile to the northward of Bestwood Lodge, and are probably the remnants of a once-continuous deposit.

About ¾ mile S. of Bestwood Lodge, or 600 yds. S.W. of Redhill Farm, at about 280 feet above O.D., a small pit has been opened in a low gravel-capped rise, which shows 6 ft. of stratified red sand and gravel containing a few small boulders of hard yellow sandstone (Carboniferous?) and other erratics, among which a fragment of andesite was noticed. This place lies ¾ mile W. of the village of Arnold, and we learn from Shipman's notes[1] that a few scattered boulders of larger size have been observed in the neighbourhood, notably one of white granite, measuring 44 in. by 38 in. by 38 in. at the Workhouse Lodge, Bagthorpe, and another, of olivine-dolorite 21 in. by 20 in. by 9 in. on the Mansfield Road near Daybrook.

A mile farther westward, in the little valley between Top-valley Farm and Forest Farm there is a rude terrace of gravel which has at one time been dug in small pits now obscured; but this strip of gravel, too small to be shown on the map, is evidently newer than the high-lying drift above described, and probably belongs, like the irregular terrace-gravels of the Leen Valley from Bulwell southward, to the closing stage of the Glacial period, when all the valleys were swept by heavy floods.

The Bulwell gravels above referred to are fouud in ill-defined patches on both sides of the Leen, usually occupying the crest of slopes rising 40 or 50 ft. above the alluvium of the valley-floor. They are slightly exposed in a small section 100 yds. N. of Bulwell Church, and still better in a gravel-pit on the E. side of *Highbury Road*, 250 yds. S.S.E. of the same church, where they are dug to a depth of 9 ft. and contain a few far-travelled blocks, among which andesite, presumably from the Lake District, was again noticed. These two exposures lie slightly beyond the western margin

[1] Shipman's MSS. in University College, Nottingham.

of our map; but the next, at the entrance to the new Tramway Station 400 yds. S.E. of the last, where 6 ft. of similar drift is visible, falls just within the map. South of Highbury Vale no clear section was seen until we reach the patch around Bulwell and Basford Station, which is exposed to a depth of 3 ft. in a road cutting in *Park Lane*, 400 yds. S.E. of the above station. Then, on the E. side of the Leen, there is a gap of over a mile in which these particular gravels are either absent or are represented merely by a foot or two of stony subsoil, though on the opposite side of the valley there appears to be a capping of gravelly drift on the bold rise W. of Basford. The gap occurs where the valley of the Day Brook joins the Leen; and the evidence indicates that this little valley has been eroded since the drift was accumulated, the delta-like terrace of more recent gravel of lower elevation, which occurs on both sides of the Day Brook at the confluence of the two valleys, being in part derived from the waste of the older gravel.

The drift-gravel, however, sets in again strongly on the crest of the slope east of the Leen at *Bobbers Mill* (between Basford and Radford), and is well exposed, up to a depth of 8 ft., in a large sand-pit in which the underlying Bunter Sandstone is dug (p. 32). The gravel contains blocks of yellow Carboniferous sandstone and other erratics, among which a boulder of Gannister sandstone, measuring 14 in. by 12 in. by 6 in., and one of andesite 15 in. by 6 in. by 4 in. were noted. The deposit appears to extend for 400 or 500 yds. along *Bobbers Mill Road*, forming a little plateau, broken through on the south by a small valley of later erosion along which the lower portion of *Alfreton Road* is carried. On the spur S. of this valley sandy gravel is again seen to a depth of 3 ft. in a shallow road-cutting, and it probably extends as far as the churchyard of *St. Peter's*, but is nowhere well exposed.

There is also a gravelly surface in many places on the rising ground between Radford and the Trent valley, particularly along *Radford Boulevard*, 100 yds. S. of *All Souls' Church*; but the ground is so much covered by buildings that it is impossible to recognize whether this represents the glacial drift or the downwash from the Bunter Pebble Beds. The gravelly lower terrace on the eastern angle between the valleys of the Leen and the Trent is classed, along with the obscure terraces of similar elevation W. of the Leen between Basford and Lenton, as Post-glacial river-gravel.

On the angle of rising ground W. of the mouth of the Leen Valley at Lenton there is an interesting patch of high-level gravel which rises to about 40 ft. above the level of the river, and is probably a late-glacial flood-gravel, slightly newer than those previously described in the higher part of the valley. The deposit is well exposed at the top of the moulding-sand pits at *Spring Close*. It rests upon the Lower Mottled Sandstone of the Bunter, in irregular hollows of erosion, somewhat complicated by shallow contortions. The gravel, as at present exposed, nowhere exceeds 7 or 8 ft. in depth and is usually thinner; but Shipman, in a description of this section as it appeared in 1879,[1] mentions a thickness of 10 or 12 ft. in the deepest part; and we were informed at the pits that it had exceptionally reached 20 ft. in thickness. The pebbles are chiefly of quartzite and quartz derived from the Bunter, with a few flints, but Shipman mentions the occurrence also of "other rocks that do not belong to this district at all." Like most of the old gravels of the district, it is in places much crumpled and contorted, which may have been caused by the impact of river-ice at the time of its accumulation, or, more probably, by later "creep" or soil-cap movement to which these incoherent superficial deposits appear to have been peculiarly subjected, perhaps, in part through alternate freezing and thawing when waterlogged, and in part through slow and irregular subsidence, following the removal of soluble or finely divided matter by percolating water. The presence of these contortions was supposed by Shipman, in agreement with the opinion of Mr. R. M. Deeley,[2] to indicate that the gravels were of "Interglacial" age (see p. 68).

[1] 'Alluvial and Drift Deposits of the Trent Valley. Lecture, republished from *Ann. Rep. Notts. Nat. Soc.* for 1879 (Nottingham, 1880), pp. 10, 11, and Fig.

[2] 'The Pleistocene Succession in the Trent Basin.' *Quart. Journ. Geol. Soc.*, vol. xlii, 1886, pp. 472-4.

In his paper on the "Alluvial and Drift Deposits of the Leen Valley" above referred to, Shipman described the superficial deposits exposed in digging the foundation for a gasometer in the valley-bottom at Basford, where, beneath a varied sequence of recent alluvial beds (see p. 85), and old flood-gravel ("torrential gravel") he found a lenticular mass of stony loam and sand, studded with pebbles and small boulders, including some Carboniferous sandstones, which he considered to be of glacial origin, and, in fact, a local kind of "boulder-clay." The material is probably similar to the stony loam which occurs on the lower slope of the Greet Valley, presently to be described. It is unlikely that a true glacial boulder-clay exists in the position indicated, as the Leen valley does not appear to have been eroded to its present depth until after glacial times.

The presence of a patch of high-level gravel on the crest of the Trent bluff just above the racecourse at Colwick has already been mentioned. Most of this gravel has been dug away, so that now it is only just practicable to recognise its occurrence, and we are indebted to Shipman's MS. notes for directing our attention to the spot. Shipman saw the section when the gravel was being dug, and his record states that the pit was 150 yds. in its greatest length, but only 3 to 5 ft. deep; pebbles were most abundant on the W. side of the pit, in a matrix of red marly sand, and were of quartz and quartzite, some large and some small, with large lumps and slabs of sandstone, some from the Keuper and some like Coal-measures sandstone (one block measuring 24 in. by 5 in.), often angular but occasionally rounded, and generally lying with their longer axes vertical: no flints were seen.

A similar but more extensive patch of high-level drift occurs on the top of *Wilford Hill*, on the S. side of the Trent due S. of Nottingham, which rises steeply to over 250 ft. above O.D. The outer fringe of this drift just crosses the margin of the present map; but as the main mass of the deposit lies south of it, in the adjacent Sheet 142, its boundary has been drawn, for convenience in printing, at the edge of the last-mentioned Sheet. This drift was recently well exposed in the construction of a waterworks reservoir on the top of the hill. It consists of a very irregular and confused admixture of reddish loamy sand, clayey gravel, and loam, highly contorted and running into each other in steeply-tilted lenticles or 'tongues.' This material was exposed to a depth of 10 or 11 ft., and the bottom was not reached. The pebbles were nearly all quartzites, etc., from the Bunter, with a few lumps of skerry-sandstone from the Keuper; they mostly lay with their longer axes vertical. By Mr. R. M. Deeley this deposit has been classed as "Chalky Gravel," and is supposed to be newer than the "Quartzose Sand" of the valley of the Wreak to the south, and of Annesley to the north[1]: but the recent sections showed no Cretaceous detritus among the pebbles; and there seems no reason for separating this Wilford Hill drift from the high-level drift north of the Trent, which it essentially resembles.

Owing to the downwash of this drift over the long slopes of Keuper Marl, the soil of the area mapped as driftless in the south-western part of the map is rendered loamy and pebbly, often differing much from the stiff red clay soil proper to the Marl. It is, indeed, possible that there may be thin patches of gravel in place on these slopes; but the available evidence points more strongly to the modification of the soil being due to downwash.

G. W. L.

The indefinite drift of the country east and south of Bingham is composed largely of Keuper Marl or Lias Clay, according to the character of the underlying formation, with flints and quartzite pebbles, and in lesser quantity, boulders and pebbles of whitish or yellow sandstone, yellow chert and Lias limestone. It attains its maximum development on the ridge of Keuper Marl between Whatton Manor and Northfield House, to which it forms a capping, and is said to be about 6 ft. thick. In other

1 'On the Pleistocene Succession in the Trent Basin.' *Quart. Journ. Geol. Soc.*, vol. xlii, 1886, p. 464.

places, however, the thicker drift lies in the hollows. Thus, the extensive patch N. of Aslockton forms, in the main, low ground, and towards its N. end occupies a valley between two ridges of Keuper Marl. This drift is 4 or 5 ft. thick, and very variable in character, being in places quite clayey, and in others loamy, sandy, and even gravelly. Good sections are visible in the ditches and waterholes almost everywhere in this low-lying drift, and nearly all reach the underlying Keuper Marl at a depth of 4 or 5 ft.

Wiverton Hall is built on an 'island' of loamy and clayey drift, rising out of the alluvial flat; and some moundy deposits of sand and gravel rise above the more southerly portion of the same flat.

The drift of the small area shewn on the map W. of Cotgrave attains a thickness of several feet; and as this appears to continue southward into the undoubted glacial drift of Sheet 142, its glacial origin may be accepted with more confidence than in the case of the detached patches above described. It is a red clay or loam, with boulders of sandstone and pebbles of quartzite, yellow chert, &c. A boulder of coarse grit, 2½ ft. by 2 ft. by 2 ft. lying by the roadside ¼ mile S.W. of Cotgrave Rectory has presumably been found in this drift.

Only five other boulders exceeding a foot in diameter were observed in the country S.E. of the Trent, and they all lay within the driftless area. Two of these occur close to the Old Hall at Carcolston: one being a round boulder of bluish pebbly grit, measuring 2 ft. by 2 ft. by 1½ ft., which lies close to the edge of the large pond at the bend of the road N. of the Old Hall; and the other, a boulder of sandstone, of similar shape and size, on the roadside immediately E. of the Old Hall. We were informed that though these blocks have been removed to their present position they have been lying in the neighbourhood as long as any one can remember. A smaller boulder of rotten felspathic grit, measuring ½ ft. by 1 ft. by 2 ft., lies near the stile on the S. side of Little Green, Carcolston; a rounded boulder of yellow sandstone 15 in. in diameter was found in a field ¼ mile S.E. of Bar Farm, on the Foss Way; and a block of much-decomposed red granite, with black mica, which measures 1½ ft. by 1½ ft. by ½ ft., occurs in a horse-pond N. of the smithy in the village of Newton. None of these boulders shows any sign of artificial cutting, and the majority are too decomposed to be of any use for building purposes; but it is still possible that, with the exception of the one at Cotgrave, they have been artifically introduced.

W. B. W.

In many parts of the Lias outcrop, in the eastern portion of the map, there are irregular pockets of sand and gravel containing flints, usually entangled with the contorted top of the Lias clays, and too sporadic and uncertain to be coloured on the map, though the areas in which they are most prevalent are indicated by engraved words. In the tracts thus indicated the otherwise tenacious clay-soil of the Lias is more or less modified by the incorporation of this less coherent material.

The best exposure of this drift is at the top of the Hydraulic Limestone quarries at Barnstone (p. 64) In these sections, beneath a foot or two of clayey soil, there is a fairly continuous deposit of reddish sandy gravel, in places reduced to a mere streak or cut out altogether for a short space by the bulging up of the Lias, and in places swelling into loops or "pockets" ranging up to 6 ft. in depth, overhung and almost enclosed by walls of contorted Lias which usually bend over toward the south. The pebbles mixed with the sand include chalk flints, chert, worn *Ostrea* and *Gryphæa* from the Lias, and quartzites, &c., derived from the Bunter (a pebble of fossiliferous Silurian sandstone being noticed among the last-mentioned).

Similar drift is evidently present in the tract between Staunton and Balderton, though scantily exposed, and probably often deeply covered by clayey wash. In a well-sinking, 400 yds. N. of Staunton Grange, a small "pocket" of sand, resting on Lias, was found beneath 7 ft. of clayey detritus and soil.

A much more decided tract of sand and gravel, considered to be of Glacial age, occurs at an elevation of 100 to 120 ft. above O.D. on the Lias plateau

east of Beacon Hill, at the north-east corner of the map. This is best exposed at the top of a limestone quarry 350 yds. W. of the windmill S. of the Moat, near Coddington, where sandy gravel, composed mainly of Bunter material, with numerous flints and some fragments of Carboniferous chert, attains a depth of 8 ft. ; and this is probably not its maximum thickness, as the section is near the edge of the gravelly tract.

G. W. L.

Older River Gravels (Late Glacial Flood Gravels).

GENERAL ACCOUNT.

Under this term we shall describe certain gravels which lie well above the Trent Flats, but are still evidently associated directly with the river.

The geological history of the Trent has yet to be written, and will need much further research over the whole basin for its elucidation. So far as our evidence goes at present, the long straight trench which the river occupies between Nottingham and Newark has been excavated since the glaciation of the country, as the river-gravels are always found to rest upon a floor of the solid formations, and in no instance has recognisable glacial drift been discovered within the trench. Nevertheless, as the bones of extinct mammalia, including the mammoth, hippopotamus and rhinoceros, occur in the valley deposits of the Trent basin above Nottingham,[1] it is evident that the river had established its present course before the close of Pleistocene times, and probably not later than the close of the Glacial period. By some geologists, indeed, as previously mentioned, these older gravels of the Trent are regarded as "Interglacial," and there is supposed to have been a recurrence of glaciation in the valley subsequent to their deposition.[2] This opinion is based mainly upon the prevalence of contorted structure in the gravels and the presence of stony loam above them in some places. But the contortions do not necessarily imply the passage of an ice-sheet, and the stony loam lacks the characters of a true boulder-clay. No evidence was found for this supposed separate and later glaciation during the survey of the higher portion of the Trent basin[3] lying in Sheets 141 and 156 ; and the mapping of the present sheet has yielded the same negative result. The gravels associated with the Trent appear, on the contrary, to imply that there has been no interruption of the fluviatile conditions in this part of the valley since the river was established in its present course. Nor, from the physical conformation of the surrounding country, does it seem probable that glaciers were revived in its shallow valleys at a period subsequent to the great glaciation indicated by the Chalky

[1] See 'The Geology of the Country between Derby . . . and Loughborough' (*Mem. Geol. Surv.*), 1905, pp. 41-42; also Bemrose & Deeley. *Quart. Journ. Geol. Soc.*, vol. lii, 1896, pp. 497-509.

[2] R. M. Deeley, 'The Pleistocene Succession in the Trent Basin.' *Quart. Journ. Geol. Soc.*, vol. xlii, 1886, pp. 467 *et seq.*

[3] C. F. Strangways, 'Geology of . . . Derby,' etc. (*supra cit.*), pp. 39-41 ; and 'Geology of the Country near Leicester,' pp. 43-54.

Boulder-clay; and this boulder-clay is always trenched by the valleys.

It is, however, certain that not only the older but also the less ancient gravels of the Trent valley were accumulated under conditions very different from those which now prevail, and at a time when the river and its tributaries far exceeded their present volume, and were much more powerful both in erosion and in transport. These conditions are such as are likely to have obtained at the close of the Glacial period, when the land was ridding itself of its icy burden, and when the winter downfall was still accumulated as snow, to be released suddenly by the thaw of the early summer, causing heavy seasonal floods in all the streams. In countries where these conditions still persist, *e.g.*, in Iceland, Alaska, and in the mountainous parts of Central Asia, it is found that wherever the gradient is not very steep the drainage channels are choked with gravelly detritus brought down by the floods in greater quantity than can be discharged from the valleys, so that extensive flats are built up on the valley floors, in which the overloaded streams are often split up into many branches, with ever-varying channels. All the features observed in the broad gravel flats of the Trent and its tributaries tend to show that these deposits were mainly accumulated in like manner from the overburden of the floods.

Just before they enter the present map, the Trent Flats are bordered on the north western flank by an irregular platform of the older gravel, which rises above the flat and forms the site of the village of Beeston.[1] The previously-described patch of gravel on the western side of the mouth of the Leen Valley at Lenton (p. 70) occurs at approximately the same elevation above the flat and, as already mentioned, may represent the same stage. Though too indefinite to be mapped, there are also slight indications of a high-level terrace in the grounds of Gedling House, 3 miles E. of Nottingham; but with these exceptions the older gravels are not in evidence on the northern or left side of the Trent until we reach the confluence of the Greet, having probably been swept away by the later erosion which carved out the steep straight bluffs that characterise this portion of the valley.

On the opposite or southern side of the river, however, south-east of Nottingham, where the trench is much less sharply defined, the valley-floor is bordered for 3½ miles by a higher fringe of gravel, which in places forms a curious ridge-like feature and rises to over 20 ft. above the flats.

G. W. L.

DETAILS.

Where the gravel just mentioned is first seen, on the south of West Bridgford, it is banked against a rising slope of Keuper Marl, as was clearly shown in some recent excavations for drainage in laying out the new building land on the W. side of the high road to Edwalton; but E. of this

[1] See 'Geology of the Southern Part of the Derbyshire, etc., Coalfield' (*Mem. Geol. Surv.*), 1907, p. 168.

road the Keuper slope begins to fall back, leaving a slight depression on the inner side of the gravel-belt, and the ill-defined ridge thus initiated steadily gains prominence westward, until at Gamston it forms an esker-like feature striking across the mouth of a small valley draining from Edwalton. It is possible that this ridge may represent the original arrangement of the gravel ; but some of the sections indicate that it may owe its prominence mainly to the protection afforded by the gravel to the underlying Keuper Marl, which where not thus sheltered has been greatly lowered by weathering and irregularly eroded since the gravels were deposited.

The gravels have been dug at several places, particularly in the large shallow pits at Gamston described and figured by Mr. Deeley.[1] The most westerly exposure, other than the temporary sections previously referred to, is in a small road cutting 250 yds. E. of the Edwalton Road, S. of West Bridgford, where 2½ ft. of disturbed sand and gravel is seen, beneath 2½ ft. of loamy gravelly soil ; the pebbles range up to 15 in. in diameter, and the majority are derived from the Bunter, with a few flints and cherts. The pit at present being worked at Gamston is situated 300 yds. N.E. of the village. Beneath 1½ ft. of gravelly soil it shows up to 7 ft. of sandy gravel with stones like those of the last section, but with flints more numerous ; the original bedding is almost lost, and the pebbles are tilted in all directions. West of Gamston the sections are obliterated, but the extent of the gravel is indicated by the character of the soil and by the feature, and may be thus traced to Radcliffe, where it terminates obscurely.

The stony loam which fringes the southern slope of the Greet valley, from its junction with the Trent flat nearly to Southwell, has been previously referred to (p. 46). This material may possibly represent the relics of a late-glacial flood-terrace, now almost destroyed by weathering and mingled with clayey downwash from the adjacent slopes of marl. Its relatively low position in the valley, and its lithological character, tell against the supposition that this is an actual boulder-clay ; but the size and distant origin of the boulders, and the disturbed condition of the underlying Keuper, point to the presence of ice in some form, perhaps as river-floes, during its accumulation. It occurs at 10 to 20 ft. above the alluvial flats of the Greet and Trent, and, as exposed in the recent drainage trenches, attains its maximum thickness, exceeding 8 ft., on the low spur between the two flats. It consists of pebbly loam with small irregular pockets of orange or grey sand and clayey gravel (but with no clean gravel) much disturbed and mixed with the underlying Keuper Marl. Along with many Bunter pebbles, it contains numerous subangular blocks of yellow sandstone or grit, probably from the Carboniferous, ranging from a few inches up to a foot in largest dimension ; and in one place, alongside the railway 1,100 yds. S.E. of the place where the railway crosses the road at Easthorpe, a spheroidal boulder of basalt a foot in diameter, like the Derbyshire "toad-stone," was dug out of the trench at a depth of 6 ft. It may be here mentioned also that a boulder of similar rock, 1½ ft. in diameter, was noticed lying at the corner of *Jew's Lane* and South Hill road, 230 yds. S. of *Holy Trinity Church*, Southwell.

At Upton, on the N. side of the Greet valley, at its mouth, the rising ground up to 50 ft. above the flat is covered with pebbles ; and clayey and sandy gravel is seen in places to a depth of 2 ft. There are traces of shallow excavations in a field 80 yds. N.E. of Upton Church, which may be old gravel pits ; but no clear sections of the deposit are visible, so that its thickness and character are uncertain. It is probably, however, a relic of the older gravel of the Trent.

G. W. L.

At Newark, on the opposite side of the Trent Flats, the river in its present course truncates the western edge of a great platform of sand and gravel, nearly two miles in breadth, which stretches away eastward beyond the margin of the map. The greater part of Newark stands on this platform, which is here about 20 ft. above the recent alluvium of the Trent

[1] *Quart. Journ. Geol. Soc.*, vol. xlii, p. 471, and Fig. 4.

and the Devon, but rises 12 or 15 ft. higher farther eastward. In the adjacent maps, Sheets 70 and 83 (Old Series), these gravels have been traced continuously north-eastward across the low watershed into the basin of the River Witham near Lincoln ; and it has been shown by Mr. Jukes-Browne that they represent the course of the Trent in early Post-glacial times when the river probably flowed through the Lincoln Gap and had its independent estuary to the North Sea in the direction of the Wash.[1]

The edge of the platform on the south and west where it rises above the more recent alluvium is slightly elevated above the general level, and other low ridges occur in the interior of the platform, running generally east and west. The S. margin of the flat, after crossing the Great North Road, reaches the Rhætic escarpment, against which the gravels are banked, but they slowly creep across it northwards until they come to lie level with the top, and still further on they overlap on to the Lias. The N. margin of the flat is less definite, being marked in Newark by a slope much obscured by buildings and then running parallel with the Rhætic escarpment of Beacon Hill and thinning off on its lower slopes. Outlying patches of gravel at about the same level occur at Hawton Church and near the site of Holt House on the Foss Way.

The only good section at present open in the gravel occurs alongside the Bottesford branch of the Great Northern Railway where it crosses *Hawton Lane*, ¾ mile W. of Balderton Church, in a small pit from which building sand is dug. This section shows 7½ ft. of current-bedded sand and gravel, irregularly alternating, and in places contorted and 'piped,' probably from the effect of percolating water. The pebbles are mostly small, those from the Bunter predominating, with numerous small flints and a few fragments of sandstone, etc. A small pit at Balderton, alongside the G. N. Railway, yielded, among others, pebbles of jasper containing hematite, and Carboniferous cherts.

At the Devon Brewery, Barnby Gate, Newark, the sand and gravel is 19½ ft. thick, and at Hawton Church it is said to be 4 or 5 ft. thick, so that the gravel appears to rest on a Keuper Marl plain at a height of about 40 ft. O.D., *i.e.* about 5 or 6 ft. above the level of the Trent at Newark. It is probable, however, that a buried channel lies between these places, for the large gravel pit where the road from Grantham crosses the Bottesford Branch line at Newark is said to have been dug to the red marl at a depth of 18 ft., and this, added to the 20 ft. exposed in the railway cutting, gives a thickness of 38 ft., which would be 15 ft. below the present average level of the Trent at Newark.

R. L. S.

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[1] 'On the Relative Ages of Certain River-Valleys in Lincolnshire,' *Quart. Journ. Geol. Soc.*, vol. xxxix, 1883, pp. 596-610; and in 'Geology of S.W. Lincolnshire,' etc. (*Mem. Geol. Surv.*), 1885, p. 90.

CHAPTER VII.

POST-GLACIAL RIVER GRAVEL AND ALLUVIUM.[1]

GENERAL ACCOUNT.

After the deposition of the high-level gravels described in the last chapter, the Trent excavated its broad trench deeper into the solid formations, and accumulated the newer gravels and other alluvial deposits which form the Trent Flats. Judging from the depth at which the Triassic strata have been found in borings on different parts of the flat, the floor on which the river deposits rest is fairly even and regular from side to side, but the present position of the river affords no indication as to the position of the deepest part of the old channel. At Nottingham, where borings and excavations have been comparatively numerous, the information enables us to draw the section across the river-flat shown in Fig. 6. From this section it will be seen that the solid rocks are here excavated more deeply to the northward of the present river-course, but that the old floor has a gentle gradient, and shows no sharp trenching such as would have occurred if the river, since occupying its present valley, had ever possessed an open avenue of discharge at an appreciably lower level. Therefore, although the floor of the valley is choked with old detritus that impedes the progress of the present enfeebled stream, there is no indication of a "buried valley" in this part of the Trent basin, and the phenomena seem to require only that the river was formerly much augmented in volume while flowing at approximately its present level.

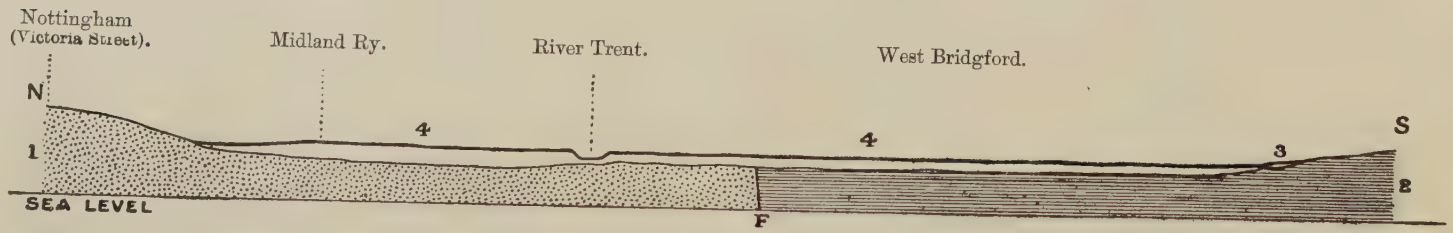
Whether the Trent held its present course through this ground in Pre-glacial times is doubtful, no satisfactory evidence having yet been found that the valley between Nottingham and Newark was in existence prior to the great glaciation. The oldest river gravels, however, as previously stated, carry back the antiquity of this portion of the river at least to the closing stages of the Glacial period and the erosion of its trench must have progressed rapidly down to the period of the newer gravels with which the floor is now overspread. Since the accumulation of these later gravels, though the river has probably widened its valley to a slight extent, there has been practically no deepening of the trench. On the other hand, the tendency has been rather toward a levelling up of the inequalities of the valley floor by the deposition of detritus brought down by the side streams.

The gravels of the main river were deposited in slightly raised belts and broad low spits, usually elongated in the direction of the valley, the river having apparently spread, during this stage, across the whole width of its flat, probably dividing into

[1] By G. W. Lamplugh, W. B. Wright, and R. L. Sherlock.

Fig. 6.—Section across the Trent Valley from Nottingham to West Bridgford.

Horizontal Scale, 3 *in.* = 1 *mile*. *Vertical Scale*, × 6.



4. Alluvium and River Gravel.
3. Older River Gravel.
2. Keuper.
1. Bunter.

F. Fault.

numerous branches that were constantly swinging and changing their courses. The low undulations of the gravel-flat thus formed have since been partly obliterated by the clayey sediment derived from the Keuper Marl by the tributary streams, and there is thus much local diversity of composition in the subsoils of the Trent Flats. Reddish-brown loamy clay, often several feet in thickness, occurs around the mouths of the small valleys, and spreads outward from them in broad fans which thin off gradually above the gravel, as may be well seen opposite the confluences of Cocker Beck, Dover Beck, and the River Greet with the main valley. In other parts of the Trent Flats, which were sheltered from these red clayey sediments by intervening bars of gravel, there have been local accumulations of stiff grey mud, containing much vegetable matter and thin seams of peat, which also tend to fill up the original inequalities of the river-gravels.

Red loamy clay similar to that above described has also accumulated in many places in the tributary valleys, forming small alluvial flats in which it sometimes reaches a thickness of 8 or 10 ft., as, for example, in the middle reaches of Halloughton Dumble, and along the Cocker Beck below Lambley. The present streams have cut deep narrow gullies through this deposit, revealing its homogeneous and loess-like character. At its base there is frequently an irregular bed of gravel or rubble derived mainly from the 'skerry'-sandstones and Waterstones, associated with sandy and muddy seams containing land and fresh-water shells, plant-remains and a few mammalian bones. The collections made from this material in Cocker Beck and Halloughton Dumble (p. 86–7) include relics of man, and indicate that the deposits are not of earlier date than Neolithic.

The greater part of the country south-east of the Trent is drained by the River Devon (which joins the Trent at Newark) and its tributaries, the Smite, and Car Dyke. In connection with this drainage system there are extensive alluvial flats, usually underlain by dark loamy clay derived from the Lias and Rhætic formations, but sometimes including considerable areas of white shell-marl with a thin covering of peaty loam. In this quarter, where the drainage gradients are very low, temporary accumulations of still or sluggish water and tracts of bog-land persisted until artificially drained.

On the northern side of the Trent south and west of Nottingham, the broad alluvial flat is very slightly raised above the river and in many parts is still within reach of high floods. Where the streets have spread across this flat most of the ground has been artificially raised to afford building sites, and this operation is still in progress around the southern suburbs of the city. At the surface of the flat there is usually a bed of loam, more or less clayey, beneath which are found river-gravels, extending downward to the Triassic floor of the valley. The loam probably represents the deltaic deposits of the River Leen and Tottle Brook, with some addition from the flood-waters of the main river. The gravels emerge at the surface in a few

places that are raised slightly above the general level, the larges patch lying between the Beeston Canal and the Trent Junction branch of the Midland Railway at Dunkirk.

The occurrence of mammoth remains in the Trent alluvium is mentioned by Shipman (in the second paper cited below), but the discoveries did not come under his own observation. Referring to an account given in "White's Notts. Directory for 1864, p. 72," he remarks that the section said to have been met with in excavating a large well for a gasholder in Island Street, Nottingham, just on the margin of the alluvial plain, was :— Soil, 3 ft.; sand and silt, 10 ft.; gravel, 11 ft.; and "amongst other things found here were part of the skull of a deer, and an enormous tooth (probably of the mammoth). . . . . Two teeth of the mammoth (*Elephas primigenius*) were found about 6 ft. deep in the alluvial brick-earth or clay on the Clifton side of the valley some years ago. A few bones were also met with in sinking the shafts for the Clifton Colliery in 1869, but no scientific examination or record appears to have been made of them."[1]

Shipman suggests that the mammoth remains above mentioned may have been washed out of some older deposit, but it is not improbable that they may really belong to the period of the river-gravels. In the Nottingham Museum there are three large molars labelled "from the River Trent opposite Barton Ferry"; and the small museum at Newark Castle contains a worn molar (measuring 5 ins. by 3 ins. across the crown) which is reported to have been obtained in dredging gravel from the bed of the Trent near Gunthorpe Bridge. These are much water-worn; but another specimen in the Nottingham Museum labelled, "Found 8 ft. deep in old alluvial sand, in St. Michael Street, Nottingham," does not appear to have been rolled.

G. W. L.

DETAILS.

Trent Flats N. of the River.—The alluvial deposits of the Trent valley near Nottingham have been carefully described by Shipman,[2] who had the opportunity to examine sections which are now no longer available. We are indebted to his descriptions for the following particulars :—

"The valley bottom deepens, and the thickness of the alluvial deposits of the Trent therefore increases slightly, as we approach the middle of the valley . . . Thus, at Clifton Colliery 25 ft. of alluvial gravel and soil was passed through before reaching the solid rock beneath. At Highfield Park boring, a few yards north of the railway, the alluvium was found to be 22 ft. thick; and at Chilwell boring [Sheet 125], a mile and a half north-west of that in Highfield Park, but rather nearer to the side of valley, only 16 ft. of alluvium was passed through.

"The alluvial gravel of the Trent is composed for the most part of a

[1] 'Description of some Borings on the Clifton Estate,' etc., by J. Brown, *Trans. Chesterfield and Derbyshire Inst. Engineers*, vol. viii, 1881, p. 351. There is no evidence, however, that these bones were remains of mammoth.

[2] 'Notes on the Alluvial and Drift Deposits of the Trent Valley near Nottingham' (a Lecture delivered to the Nottm. Nat. Soc., November 5th, 1879), reprinted, with additions, from *Ann. Rep. Nottm. Nat. Soc.*, Nottingham, 1880. Part of this paper is also incorporated in the author's 'Geology of the Parish of Lenton' (see footnote on p. 85, and Appendix II.), from which the extracts given above are quoted, pp. 43–46.

great variety of well-rounded quartz and quartzite pebbles along with sub-angular, or less rolled, pebbles of Carboniferous Limestone chert, Coal Measure sandstone, and Millstone Grit, Keuper sandstone, Lias, and flints, and a few other rocks that have probably travelled from the far north. Many of the quartz and quartzite pebbles were most likely derived from the wearing down of the Bunter, but a large proportion of the pebbles would seem to have been brought from the north and swept into the valley during the Glacial Period."

In an excavation made, under Shipman's direction, in the alluvium at Highfield Park "close by the spot where the Tottle Brook enters the Trent valley" . . . "about 6 ft. of clay was passed through without reaching the gravel on which it probably rests."

As shown in Fig. 6 (p. 78) the river deposits become shallower toward the S. side of the valley at Nottingham, so that the solid formations are laid bare in the bottom of the Trent in the loop above *Trent Bridge*, (p. 22). In borings made to test the ground for the foundations of the Suspension Bridge recently erected in this loop, 1,000 yds. above *Trent Bridge*, where the surface was about 18 ft. above the water-level of the river in summer, the Keuper Marl was reached at depths varying from 8 to 11 ft. on the W. side to 13½ to 18 ft. on the E. side, thus showing that the river is actually channelling the 'solid' floor of the valley at this spot. The alluvium in these borings consisted of gravel, with 5 to 6 ft. of loam covering it in the sections nearest the river on the E. bank.[1]

East of Nottingham, on the N. side of the river for 2 or 3 miles, the composition of the alluvial flat is very similar to that of the tract W. of the city, patches of sandy gravel rising slightly in places through the superficial covering of loam or clay, while beyond Netherfield the gravels occupy a much larger proportion of the surface and rise more definitely in banks and platforms above the newer alluvium.

Opposite Sneinton the alluvium includes a band of peat, which was exposed in a sewage trench in *Trent Lane*, between the Midland and Great Northern railways, examined by Shipman [2]; the peat was from 12 to 18 in. thick, and occurred at a depth of about 4 ft. beneath red loamy clay or brick earth. It yielded hazel-nuts and the bones of ox (*Bos longifrons*) now preserved in the Nottingham Museum.

A similar bed of peat was trenched, 400 yds. farther E., in the foundations for the railway bridge of the Great Northern suburban branch over the high road to Colwick. Again, at the Colwick Sewage pumping-station, the following sections were disclosed[3]:—

1. Section on S. side of the G.N. Ry. 800 yds. S.W. of the Netherfield Station (surface-level 75½ ft. above O.D.).

	Ft.
Red clay	10
Peat	2
Blue clay	1
Dark "Ballast" [clayey gravel]	11
Red Gravel on Marl [Keuper Water-stones]	7
	31

2. Section about 30 yds. E.N.E. of No. 1 (surface-level 3 ft. higher).

	Ft.
Sandy red clay	8
Sandy black clay	5½
Peat	2½
Blue clay	3
Light loamy sand	1½
Dark "Ballast"	5
Red "Ballast" on Marl [Keuper Water-stones]	8
	33½

In cutting the drains on the N. side of the railways at *Lockerbie Street*, between Colwick and Netherfield, the peat was found to occupy a hollow in the gravels, thickening to 4 ft. in the deepest part, and there covered by

1 We are indebted to the Nottingham Corporation Water Board for this information.

2 Shipman's MS. Notes, preserved at the University College, Nottingham.

3 From information supplied by Messrs. Elliott & Brown, Civil Engineers, Nottingham.

3½ ft. of gravel and clay, but thinning and rising close to the surface on both sides of the hollow.

It is probable that this peat and the overlying deposits have filled and obliterated an old channel of the Trent, when the river ran close under the northern bluffs of this part of its valley.

At Netherfield the Trent gravels have been very extensively dug for ballast in pits adjacent to the Great Northern railway[1]. The best section at present exposed is in the large pit on the E. side of the Colwick sidings, which shows about 12 ft. of current-bedded gravel and sand, overlain in the S.W. part of the section by earthy soil which thickens rapidly north-eastward to a bed of pebbly loam from 2 to 4 ft. in depth, this loam being evidently derived from the slopes of Keuper Marl which bound the valley. Most of the pebbles in the gravel have been derived from the Bunter, but there are also many Chalk flints and some fragments of Keuper sandstone and of Carboniferous rocks including black chert, sandstone and, occationally, limestone, along with a few igneous rocks, probably representing the erosion of boulder-clays.

Between Netherfield and Burton Joyce the gravels form a broad undulating flat, which ends in a well-defined bank at its outer margin, and is furrowed by the erosion-channels of the rivulets which drain it. The greater part of this tract is occupied by the Nottingham Corporation Sewage Farm, which also extends across the Trent Flats between Burton Joyce and Gunthorpe.

At Burton Joyce the deep boring for water near the edge of the flat (see p. 98) yielded the following section :—

	Ft.	In.
Soil	1	0
Loam	2	6
Clay	0	10
Gravel	18	5
On Keuper Waterstones.		
	22	9

Another section at Burton Joyce, 700 yds. S.W. of the above, and on the S.E. side of the railway, 350 yds. E.N.E. of the church, in a recent excavation made for drainage, showed 13 ft. of gravel overlying the Keuper, and overlain by 3 to 4 ft. of pebbly loam.

The diversity of the subsoil on the Trent Flats, to which reference has been previously made, was well illustrated, while the survey was in progress, by a series of deep trenches opened up across the Sewage Farm between Burton Joyce and Gunthorpe for the conveyance of the liquid effluent of Nottingham. These trenches revealed many local changes in the character of the alluvium that could not otherwise have been detected ; and except by artificial aid of this kind, it is rarely practicable to trace out its constantly varying composition in detail. On the low ridges and rises, the river-gravel usually emerges at the surface, and its bottom was not reached in any of the trenches that were open to examination. Where the Cocker Beck debouches on the flat, near Lowdham, the gravel is covered by several feet of red loamy clay which spreads out widely on both sides, and is continuous on the north-east with a similar deposit brought down by the Dover Beck. Between Bulcote and Gunthorpe S.E. of the Midland Railway, in a tract more remote from the Cocker Beck, the alluvium consists of stiff dark mud and grey silt from 2 to 4 ft. thick, with thin peaty layers, and grey marl at the base in places, resting on the Trent gravels ; and in the lower portions of the flat adjacent to the present course of the Trent the gravels are irregularly covered by rather sandy loam. It is impossible on the 1 in. map to indicate all this diversity, but the composition of some portions of the alluvial flat is shown, where practicable, by printed words, and the river-gravels are, as usual, distinguished by a separate colour.

Between Gunthorpe and Bleasby the flats exhibit the same variety of material, but without presenting the same opportunity for examination.

[1] These are an extension of the pits at 'Carlton Field House' described in the former Memoir ('Geology of the Country around Nottingham,' 2nd ed., p. 40).

The gravelly tracts now tend to rise more markedly above the rest of the flat, for although the surface of these gravels falls gradually along the valley from about 80 ft. above O.D. at Nottingham to about 45 ft. near Newark, the gradient of the more recent alluvium is just a little in excess of this, and its level, roughly corresponding to the present limits of river-floods, become relatively lower. The definiteness of the features thus caused is well seen along the margin of the elongated tract of gravel on which Hoveringham stands; and again near Bleasby, where the gravels occupy the greater portion of the flat. All along the valley these Trent gravels are dug in many small pits, for various local purposes, especially in places where they include beds of sand suitable for building, but the individual sections do not present features that call for special description. It may be noted, however, that the pebbles in the gravel become decidedly smaller and the sand more abundant as we pass down the valley.

The deep boring near Thurgarton Station (see p. 113) gave the following section in the superficial deposits:—

	Ft.	In.
Soil	0	6
Blue sandy clay	4	0
Sand and gravel	11	4
Coarse gravel	3	0
Gravel	2	2
On blue and red clay (Keuper).		
	21	0

We are informed by Mr. F. Rayner that at Gunthorpe Bridge the Keuper Marl was reached at about 20 ft. below the surface of the left bank and extended at this depth in a flat floor under the river. The level of the solid formation is here 38 ft. above O.D.; but at Averham Weir, near Newark, where the river swings to the middle of its flat, Mr. Rayner finds that its bed has been scoured down by the current to only 15 ft. above O.D. without reaching the marl. The bottom of this eroded hollow in the river bed is only 2 ft. above the surface-level of the water in the tidal portion of the river at high spring-tides.

At Bottom Lock, just below the railway-bridge at Newark (in Sheet 113), the Keuper Marl was reached at 15 ft. above O.D., under about 20 ft. of gravel.

G. W. L.

From Bleasby, a broad stretch of gravel extends beyond Morton and Fiskerton, until interrupted by the red loam brought down by the River Greet. On the north side of the Greet, the gravels appear at the surface again at Rolleston, and continue to occupy the middle of the broad flat up to the margin of the map. In places these gravels rise slightly above the 50 ft. contour, and are therefore very little lower than the plateau running eastward from Newark, as previously described. They are exposed to a depth of about 8 ft. in a ballast pit alongside the railway at Staythorpe, consisting here of fine gravel and sand.

On the opposite side of the river around Farndon, and extending northward into the angle between the Trent and its tributary, the Devon, near Newark, there is a broad terrace of gravel at a slightly lower elevation than those above described. This tract is definitely below the level of the Newark plateau, but rises in a distinct feature to a height of 7 to 10 ft. above the recent alluvium of the Trent.

R. L. S.

The gravels of this portion of the valley doubtless represent, in one part or another, all the stages between the period represented by the Newark plateau and the present time; but it is difficult, with such slight differences of level, to distinguish their consecutive relations.

The navigable branch of the Trent which flows from Averham Weir to the confluence of the Devon on the S.W. outskirts of Newark is in part the result of artificial changes during comparatively recent times. In fact the whole course of the river up to Nottingham is now to some extent artificial, as care is taken to maintain the navigable channel by dredging and

other works, and to prevent the formation of bars and gravel-banks which in former times would tend to divert it at intervals.

G. W. L.

Trent Flats S. of the River.—On the S. side of the Trent the river-gravels set in suddenly at the N. termination of the prominent bluffs of Keuper Marl at Clifton Grove, where the valley expands in an embayment to receive the tributary, Fairham Brook. Here the gravels occupy a low terrace elevated from 4 to 8 ft. above the recent alluvium, having a well-defined outer bank, but fading off indefinitely southward.

At Wilford the terrace is composed of sandy gravel, but the proportion of sand increases eastward, so that on the S. side of West Bridgford the material is in places almost wholly sand. From West Bridgford the terrace extends more irregularly to Holme Pierrepont, its outer margin being in some places well-defined and in others merging gradually into the modern alluvial flat, while on the S. it is bordered by a strip of loam and clay brought down by small side streams.

Two wells at West Bridgford on the E. side of the Grantham Canal passed through 18 ft. of alluvium and gravel, overlying the Bunter.[1]

At Radcliffe, the Trent bends back to the S. edge of its trench and cuts out the alluvial deposits for over a mile. It then swings across to the N. side of its flat at Burton Joyce in a sharp loop, returning to the S. side at East Bridgford, and thereafter flowing at this side for nearly six miles at the foot of high bluffs of Keuper Marl, with no room for alluvium except in very narrow strips. The loop between the Cliffs of Radcliffe and East Bridgford is occupied in part by a low flat of clayey, sandy, and gravelly alluvium, and in part by a terrace of river-gravel which rises about 15 ft. above the flat. The village of Shelford stands at the outer margin of this terrace; its inner margin is partly covered by clayey wash from the bordering slopes of Keuper Marl.

The low-level alluvium in the valley above Newark, like the higher terraces from which it has been mainly derived, is largely composed of sandy Bunter waste, along with small pebbles and angular pieces of flint. The following sections will serve to show its general character :—

	Ft.	In.
At the E. point of The Nabbs Island—		
Clayey loam	2	0
Sand	0	2
Clayey loam	1	6
Sand with coal fragments	0	3
Gravel, chiefly of Bunter pebbles, mostly small, and a few flints	over 0	4
In the river bank near Farndon, ⅔ mile N.W. of the church—		
Loam, with gravelly streak at base	0	6
Sandy loam	1	6
Sand	over 1	6

R. L. S.

We have now to consider the alluvium of the tributary streams, which present many features of interest. As previously mentioned, the northern tributaries of the Trent in this map flow generally south-eastward, in the direction of the dip of the Triassic rocks, with the exception of the Leen, which has a more southerly course along the strike of the soft Lower Mottled Sandstone and Permian Marl. These dip-streams possess sharply-incised and comparatively narrow valleys in which there is little space for the development of alluvial flats. South of the Trent, however, where the streams occupy shallow longitudinal valleys of low gradient the alluvial flats are numerous and extensive.

Leen Valley.—The alluvial deposits of the Leen have been described by Shipman, who found excellent opportunity for their study in temporary

[1] From information given by Messrs. Elliott & Brown, Nottingham.

artificial sections at Radford and Basford.[1] In a large excavation for a gasholder on the W. side of the river at Old Radford he observed the following succession in the valley-deposits, banked against a slope of Lower Mottled Sandstone :—

a. Yellow, bluish, and dark grey clay.
b. Peat, with upright stems of young trees.
c. White and grey "sharp" sand and gravel.
d. Brown gravel with flakes of red hematite and thin seams of red sand near the bottom.

The peat bed contained *Quercus robur* and *Pinus sylvestris*. There were also small isolated patches of peat between the gravels, *c*, *d*, and the eroded slope of Bunter Sandstone upon which they were banked.

In a similar excavation for a gasholder on the E. side of the Leen at Basford, Shipman noted the following section, which he figured in the paper above referred to :—

	Ft.	In.
f. Grey silt or brick earth and dark surface loam 2 to	3	0
e. Peat-bed - - - - - - - - 1 to	3	0
d. Grey and yellowish laminated sand - - -	2	0
c. Ferruginous gravel with seams of bright red sand	2	0
b. "Torrential gravel" and sand - - - -	10	0
a. Glacial drift [pebbly loam] on Lower Mottled Sandstone - - - -	2	6

In this section, the beds *f*, *e*, *d*, *c*, were banked against a slope of the flood-gravels, *b*, which, in turn, overlapped an eroded surface of the supposed glacial drift, *a*. This "boulder-drift" is described as a mottled and tenacious mass of red, brown, white and greenish-yellow sand, studded with pebbles, of all sizes up to small *well-rounded* boulders, composed of quartzite, Magnesian Limestone, Coal-measures sandstone, and lumps of the underlying rock. As previously remarked (p. 71) it is unlikely that this material is a direct product of the glaciation, and more probable that, like the gravels, *b*, it is a later valley deposit.

Shipman's MS. Notes preserved in the Nottingham University College contain the details of several other sections in the Leen Valley. Among these are the following, which show a considerable thickness of peat :—

Sewer-cuttings in Vernon Road, Old Basford.

(*Shipman's MS.*)

No. 1.

	Ft.	In.
Made ground - -	5	6
Mud, with vegetable matter - - -	2	6
Peat - - - -	5	0
Yellowish gravel -	2	0
White sand - -	4	6
on Lower Mottled Sandstone.	19	6

No. 2 (going North).

	Ft.	In.
Made ground - -	5	6
Peat - - - -	4	6
Silty gravel, very loose and full of water - - -	7	0
on Lower Mottled Sandstone.	16	6

No. 3.

Made ground - -	4	6
Peat - - - - -	3	6
Wet gravel - - -	4	0
on Lower Mottled Sandstone	12	0

No. 4.

Made ground - -	5	6
Gravel - - -	2	6
Wet gravel - -	5	6
on Lower Mottled Sandstone.	13	6

These sections all indicate that the Leen Valley once held a powerful stream which eroded its channel deeply and spread its flood-gravels thickly

[1] 'The Alluvial and Drift Deposits of the Leen Valley,' *Midland Naturalist* vol. v, 1883, pp. 76–79 and 109–115 ; also included in 'The Geology of the Parish of Lenton,' in Godfrey's *History of the Parish and Priory of Lenton*, 1884 ; and separately reprinted.

over the floor of the valley. Subsequently a narrower channel was cut in these gravels by the shrunken waters, and even this channel has been filled up by the peat-bog and flood-silts of the sluggish drainage of more recent times. During the growth of the city of Nottingham the Leen has been artificially diverted from its former course along the foot of the bluffs east of Lenton. The street in the city called Leen Side is a memento of this change.

The area occupied by the Bunter Pebble Beds is furrowed by numerous long winding valleys, floored with flood-gravels, but now dry, which are tributary to the Leen drainage or to that of Dover Beck. These, like the well-known dry valleys of the Chalk Wolds of Yorkshire and Lincolnshire, were probably excavated at a time when the frozen subsoil prevented the present quick underground soakage of surface-water through the pervious sand-rock, so that torrents poured from the upland during the melting of the snows. The streams that ran in some of the deeper of these valleys are known to have dwindled and become shorter during the past half-century; and it is locally held that this effect has been accelerated by the copious withdrawal of underground water from the deep wells for public supply now established in the area (see p. 95).

Cocker Beck, Dover Beck, River Greet, etc.—Though Dover Beck and Cocker Beck discharge separately into the Trent Valley, they approach within 500 yds. of each other at the north end of Lowdham village; the occurrence of a low gap at this place in the dividing ridge suggests that the Cocker in its earliest stages may have continued its north-easterly course to Dover Beck, instead of swerving sharply southward as it now does at Lowdham.

The red clayey loam which forms the major part of the alluvium of the streams draining the Keuper upland, and the fossiliferous material which underlies it in places along Cocker Beck has been previously mentioned (p. 79). Sections showing both deposits are visible along the banks of the stream where it passes Lowdham village, the red loam being here 4 or 5 ft. thick with 1 to 2 ft. of gravelly wash and peaty mud below. The best sections, however, are those where the stream entrenches itself deeply in traversing a long narrow flat, south of Hunters Hill, between Lowdham and Lambley. Here the unfossiliferous loam is exposed up to a depth of 7 ft., forming vertical banks with an unstratified loess-like structure. This material has levelled up the floor of the valley, which is now being re-excavated; and it is in association with the older stream-wash beneath the loam that the organic remains occur.

The following is the section at the spot (750 yds. E. of Harlow Wood Farm) where most of the specimens named in the appended list were collected[1]:—

	Ft.	In.
Red loam	5	0
passing down into		
Grey and dark earthy loam, with land shells	0	6
Muddy gravel, chiefly subangular fragments of Keuper sandstone (skerry) - 1 ft. 6 in. to	2	0
Dark greenish-grey silt, with fresh-water shells and bones	2	0
Keuper Marl seen below at one place.		

From the base of the Alluvium of Cocker Beck.

Flint flakes and traces of charcoal (Neolithic).

Mammalian bones (determined by Mr. E. T. Newton, F.R.S.) as follows:—

Man (a human femur, peculiarly compressed at the upper parts).
Horse (upper grinder).
Ox (lower jaw, radius, pelvis and cunieforme of carpus)
Sheep or Goat (grinder and small metatarsal).
Pig (incisor).
Dog or Wolf (canine).

[1] The collection was made by Mr. W. B. Wright.

Mr. Newton remarks:—"The remains may be of any age from Neolithic to the present time, but it seems likely that the deposits are not of modern date. The ox-remains are small and may belong to *Bos longifrons*."

Fresh-water and Land Shells.

(Determined and preserved in the Palæontological Department of the Survey, London.)

Pisidium pusillum (*Gmel.*)
Sphærium sp.
Acanthinula lamellata (*Jeff.*)
Carychium minimum *Müll.*
Clausilia *cf.* rugosa *Drap.*
„ sp.
Cochlicopa lubrica (*Müll.*)
Helix hortensis ? *Müll.*
„ lapicida *Linn.*
„ nemoralis *Linn.*
„ pulchella *Müll.*
Limnæa *cf.* pereger (*Müll.*)
„ truncatula (*Müll.*)
Physa hypnorum (*Linn.*)
Planorbis nitidus *Müll.*
„ spirorbis (*Linn.*)
Pupa anglica ? (*Fér.*)
„ cylindracea ? (*Da Costa*)
Pyramidula rotundata (*Müll.*)
Succinea elegans ? *Risso.*
„ putris (*Linn.*)
Vertigo alpestris *Alder.*
„ antivertigo ? (*Drap.*)
„ pusilla *Müll.*
Vitrea cellaria (*Müll.*)

Besides the above fresh-water and land shells, which are all of existing British species, the silt contained the seeds of plants. These were sifted out and submitted to Mr. Clement Reid, F.R.S., who identified the following:—

PLANTS.

Ranunculus aquatilis *Linn.*
„ Flammula *Linn.*
„ acris *Linn.*
Fumaria officinalis *Linn.*
Arenaria trinervia *Linn.*
Spergula arvensis *Linn.*
Montia fontana *Linn.*
Prunus spinosa *Linn.*
„ Padus *Linn.*
Rubus.
Potentilla Tormentilla *Neck.*
Apium graveolens *Linn.*
„ nodiflorum *Reichb.*
Cornus sanguinea *Linn.*
Sambucus nigra *Linn.*
Carduus palustris *Linn.*
Solanum Dulcamara *Linn.*
Mentha aquatica *Linn.*
Galeopsis Tetrahit *Linn.*
Stachys sylvatica *Linn.*
Chenopodium rubrum *Linn.*
Rumex conglomeratus *Murr.*
Urtica dioica *Linn.*
*Corylus Avellana *Linn.*
Scirpus lacustris *Linn.*
Carex 3 or 4 sp. (*nuts only*).

*Halloughton Dumble only.

Mr. Reid adds:—"This list contains neither cultivated plants nor weeds of cultivation. It does not suggest a climate differing in any way from that now reigning in the neighbourhood."

From the above results it appears that, in spite of the thickness and peculiar structure of the overlying loam, the oldest alluvium in this part of the Cocker valley does not date back farther than Neolithic times, and has been accumulated under physical conditions not much different from the present, excepting that the surrounding country is now all cultivated and the drainage channels artificially regulated. The streams, however, under these modern conditions, can no longer become choked with forest debris, as doubtless they formerly often were, and they are no longer allowed in this manner to form swampy flats along their courses.

The alluvial deposits bordering Dover Beck are browner and more loamy than those of the Cocker, owing to the admixture of Bunter debris brought down from the headwaters of the former stream. A section on the bank just below Lowdham Mill shows 5 ft. of red sandy loam, overlying grey peaty mud and silt, of which about 2 ft. is visible above water level. The boring in the valley at Grimesmoor near Woodborough passed through 12½ ft. of sandy clay and gravel before reaching the solid floor (see p. 117).

In Halloughton Dumble the little strips of alluvium resemble those of Cocker Beck in composition, and here again, west of Rudsey Farm, organi-

remains, including the teeth of ox, were found[1] at the base of the unfossiliferous loam.

The wide alluvial flat of the Greet is mainly composed of red silty loam which also spreads out into the main valley and buries the margin of the Trent gravels. Towards the mouth of its valley the river is held to its course by embankments, and would otherwise overflow portions of the flat.

G. W. L.

Tributaries south of the Trent.—The small stream from Edwalton, and the Thurlbeck River east of Cotgrave, occupy narrow trenches where they cross the ridge of ancient gravel which stretches from West Bridgford to Radcliffe (p. 75); but to the south of this ridge their alluvial flats expand greatly, and appear to have formed the sites of bogs or temporary lakelets. The alluvium of these tracts is dark loamy clay, occasionally black and peaty, with a sparing admixture of coarse sand and small pebbles. Fresh-water shells are plentiful in this alluvium, the list given below representing a small collection, identified in the Palæontological Department of the Survey. The deep boring at Edwalton (p. 100), in the middle of one of these flats, proved 9 ft. of the surface deposits, consisting of 1 ft. of black soil and 8 ft. of sandy loam, overlying red Keuper Marl.

Land and Fresh-water Shells from the Alluvium of the Edwalton Stream, the Thurlbeck River, the Car Dyke, and the River Devon.

E=Edwalton alluvium. T=Thurlbeck alluvium.
C=Car Dyke ,, D=Devon ,,

Bythinia leachi (*Shepp.*). T.
„ tentaculata (*Linn.*). E.T.C.D.
Clausilia *cf.* rugosa *Drap.* E.
Helix nemoralis *Linn.* C.
Hygromia hispida (*Linn.*). T.C.D.
Limnæa palustris (*Müll.*). E.D.
„ pereger (*Müll.*). E.T.C.D.
Neritina sp. D.
Planorbis complanatus (*Müll.*). T.
Planorbis marginatus *Drap.* E.T.C.
„ spirorbis (*Linn.*). C.
Pyramidula rotundata (*Müll.*). E.
Sphærium corneum *Linn.* T.C.
„ rivicola *Leach.* T.
Valvata piscinalis (*Müll.*). D.
Vitrea cellaria (*Müll.*). E.
Unio *cf.* pictorum *Linn.* D.
„ ? T.

R. L. S.

The River Smite, which enters the map S. of Wiverton Hall, has in nearly every part of its course a wide alluvial flat. South of Aslockton there is usually about 3 ft. of stiff reddish-brown or grey clay resting on gravel or gravelly clay, under which the Keuper Marl can often be seen. The following section in the banks due W. of Wiverton Hall is fairly typical:—

	Ft.	In.
Brown alluvial clay	1	6
Blue alluvial clay	1	6
Stony clay or gravel	1	6
on Keuper Marl.		

North of Aslockton the Keuper Marl was not seen in the bed of the Smite except where the stream swings close to the edge of the flat.

The Whipling, which joins the Smite at Whatton, has no mappable alluvium until it breaks through the Rhætic escarpment at Barnstone, after which it flows through well-marked flats of reddish brown or grey clay or loam, containing in places flints and other pebbles derived from the drifts.

Car Dyke, which carries the drainage of the Bingham flats, and of the Carcolston springs, has in its upper reaches an alluvial flat several hundred yards in width. The sections in its banks shew about a foot of dark alluvial clay or loam overlying stiff grey clay with fresh-water shells.

The River Devon enters the map at Muston in a rather narrow valley, but W. of this village its alluvium expands into a broad flat. The river traverses this flat near its N. margin, and is bordered

[1] By Mr. W. B. Wright.

throughout its course by a strip of brown clayey alluvium a few hundred yards in width, overlying gravel and sand. The rest of the flat, lying to the S. of Bottesford, is overspread with clean sand, pebbly in places, and containing a number of small flints, which at a depth of a few feet is often seen to pass into a gravel composed of flints and fragments of Liassic limestone. The wide alluvial valley N. of Bottesford Junction contains a deposit of brown clay, with a little river-gravel at the base in places. The southern and western portion of this alluvial flat are drained by Winter Beck, which joins the Devon near Staunton just before the latter stream breaks across the outcrop of the Hydraulic Limestones in a comparatively narrow trench. On emerging from this trench and entering the Keuper Marl country the Devon once more traverses a broad alluvial flat composed of the same brown or reddish-brown clay passing locally into gravel towards the base.

W. B. W.

The valley is again constricted S.E. of Cotham Grange by the jutting forward of the faulted Rhætic-Lias escarpment, but afterwards, for the rest of its course, the Devon is bordered, often on both sides, by wide stretches of alluvium, which show a tendency to follow the outcrop of the gypsiferous marl, and may in part owe their origin to the underground solution of the gypsum. Between Cotham and East Stoke, the alluvium of the Devon and its small feeders merges into a continuous flat, nearly 3 miles wide, consisting mainly of dark brown clay, but in places passing into sandy loam, and sometimes becoming black and peaty toward the top. It usually contains a sprinkling of pebbles and chips of flint derived from the older gravels. Good sections are exposed in the Bowbridge gypsum quarries, where at the N. side of the present workings the alluvium is composed of stiff ferruginous loam 1½ ft. thick, overlying an equal thickness of ferruginous sandy gravel which is disturbed and 'piped' down into the irregular surface of the Keuper Marl. In other parts of the quarry the alluvial loam varies from 1 ft. to 3 ft. in thickness, levelling up the undulations of the Keuper and sometimes overlapping 'pockets' of the gravel.

At the Hawton gypsum quarries the sections are essentially similar to those just described, but the alluvium thickens in the direction of the Devon. The following section was observed in the S.W. part of these workings:—

	Ft.	In.
Stiff clay, loamy near the top - - - -	3	6
Loamy clay - - - - - - - 1 ft. to	1	6
Grey clay with many small pebbles and ferruginous patches - - - - - - - - - -	2	0
Fine gravel and sand, much contorted and intermingled toward the base with Keuper Marl, thickening south-westward to - - - -	3	6

The gravel at the bottom of this section contains numerous fragments of flint, together with worn gryphæas, and other debris from the Lias. The loamy clay rests upon it with a sharp and even junction, and is not affected by the contortions. Similar gravel probably underlies the loam in many parts of the adjacent alluvial flats, but is rarely visible. It appears at the surface, however, in a few places between Hawton and Cotham, on slightly rising ground which probably represents small mounds or islands enwrapped and partly buried by the later alluvium.

In the broad flats the soil is frequently black and peaty at the top, and it is often immediately underlain, as in the areas farther south, by whitish clay, slightly calcareous, and containing land and fresh-water shells. A few species of these shells which were collected from the alluvium of Car Dyke and of the Devon are included in the list previously given.

R. L. S.

Besides the alluvium definitely associated with the Devon and its tributaries, there are several low tracts in the area drained by them which appear to have been at times under standing water and are underlain by

lacustrine deposits. Of these the most extensive are the Bingham and Wiverton flats. The surface soil is generally a peaty loam averaging a foot in thickness, under which there is commonly a deposit of white shell-marl or stiff grey shelly clay, and a tenacious blue-grey or greenish clay sometimes underlies the shell marl. There are no deep sections in these deposits, but the shell-marl has been seen to a depth of 4 or 5 ft. in places. The following section, 600 yds. S.W. of Wiverton Hall, near the edge of the alluvium, is fairly typical :—

	Ft.	In.
Brown soil	1	0
Grey marl	0	9
Whitish marl with black streaks and abundant shells	0	5
Black peaty clay with stones, very stiff	0	4
Pale green clay, very stiff and tenacious	0	10
	3	4

Where these lacustrine deposits are dominated by steep slopes of Keuper Marl they are often overlain at their margin by a wash of red clay or loam from the slopes. This occurs on the S. edge of the Bingham flat, where a ditch 900 yds. W. of the station shows the following section:—

	Ft.	In.
Red clay, wash from slope	3	0
Black peaty clay	0	6
Shell marl, top grey and discoloured	1	0
	4	6

W. B. W.

Shire Dyke, which drains to the Witham, traverses a similar flat, known as Bennington Fen, part of which forms a shallow basin, enclosed by the 50 ft. contour-line.

The tract of sand and gravel bordering Bennington Fen on the E. rises to an altitude of 60 to 65 ft. above O.D. and is probably an ancient gravel of the Witham. This deposit may be as old as the Newark gravels, as the two occur at the same level and appear to be linked together by a narrow strip of similar material which follows the W. edge of the Shire Dyke alluvium E. of Balderfield. Though they show some difference in composition—the supposed Witham gravel containing more Liassic detritus and more flint—this could be explained by the different character of the drainage areas. The relations of this deposit cannot, however, be properly determined within the limits of the present map, as they depend upon the character of the country farther eastward.[1] The symbol attached to it is, therefore, that adopted on the previous map. The only good exposure is in a shallow sand pit W. of the high road about ¼ mile S. of the fifth mile-post from Newark, which showed a very variable deposit, consisting in one place of about 2 ft. of loamy yellow sand with small pebbles, resting on gravel, and covered by 1½ ft. of sandy loamy soil.

R. L. S.

1 See 'The Geology of the S.W. Part of Lincolnshire,' etc. (*Mem. Geol. Surv.*), 1885, pp. 90-95.

CHAPTER VIII.

ECONOMIC GEOLOGY.

Mineral Products; Building Materials; Water Supply; Agriculture, etc.[1]

COAL.

Although the actual outcrop of the Coal-measures in this map is very limited (p. 10), their presence beneath the newer rocks and their exploitation by pits sunk through these rocks in the western part of the Sheet render the Coal-mining industry of great and growing importance to the district. The conditions have been fully discussed in Chap. II., and detailed sections of the principal colliery-shafts and deep borings are presented in Plate I. It is unnecessary, therefore, to devote further space to this subject.

GYPSUM.

The deposits of gypsum that occur in the Keuper Marl form the basis of a considerable industry, which has its chief centre around Newark, but is, or has been, carried on also at other places within the map. The mineral occurs most abundantly at a definite horizon in the upper part of the marls, and the principal workings are all situated along this belt. It is present in thinner and less persistent veins and lenticles, at lower positions in the marls and occasionally in the underlying Waterstones.[2]

The main gypsiferous beds above referred to are approximately 60 ft. in thickness, and at Newark their upper limits approach within a few feet of the bottom of the Tea-green Marl which forms the top of the Keuper division. When traced south-westward, however, the interval between the Tea-green Marl and the gypsum beds becomes greater, owing either to the thickening of the overlying red marl or to the development of the mineral at lower levels. The gypsum occurs in irregular layers, usually 10 in. to 12 in. in thickness, alternating with partings of a few feet of marl. These layers show continual variation in their dimensions, often forming lens-shaped swellings and reticulate veins among the marl; and the upper layers occasionally expand and unite into large masses, resembling concretions, that range up to several feet in thickness, and frequently contain a core of anhydrite. At the Hawton quarries these masses are often formed by the conjunction of three bands known as the "Top White Rock," the "Middle White Rock,"

[1] By G. W. Lamplugh, R. L. Sherlock, and W. B. Wright.

[2] A good general account of the Nottinghamshire gypsum is given by A. T. Metcalfe, F.G.S., in a paper 'On the Gypsum Deposits of Nottinghamshire and Derbyshire.' *Trans. Nottm. Nat. Soc.* for 1894, pp. 19-24.

and the "Riders," while at Bowbridge they occur in the highest bed, beneath the alluvial covering. It is probable that secondary segregation through the influence of percolating waters has played an important part in the accumulation of the gypsum in these masses, as it must also have done in the production of the smaller gypsum-veins that are often seen to cross the bedding-planes of the marls and Waterstones.

Most of the gypsum in the thicker beds is of a pure white colour and saccharoidal texture, but some of the more isolated veins possess a fibrous crystalline structure and are translucent, being then used for making beads and other ornaments. The massive rock has also occasionally a slightly blue or pink tint, and lenticles of a deeper red colour sometimes occur. The deposits that are of most value commercially are those from which the mineral can be obtained in large quantities with little or no admixture of marl, as a trifling percentage of impurity spoils the product.

The mineral is used principally for the manufacture of fine plasters ("plaster of Paris"); as a "filling" material for paper, paint, etc.; and as an ingredient of artificial manures, but for the last-mentioned purpose its use in this country has greatly declined. In the preparation of plaster, the gypsum is carefully calcined and ground, while for other purposes it is ground to an impalpable powder without calcination. The rock is also used to a small extent for decorative purposes and, as previously mentioned, for the manufacture of ornaments.

Details of the sections exposed in the principal workings have been given in Chap. IV. (pp. 51–3). The quarrymen have distinctive names for the more important veins (see the sections above mentioned), while the smaller cake-like lenticular masses are known to them as "knurrs and fundlers," and similar masses united by strings of gypsum are called "riders." The material is obtained partly by open quarrying and partly by levels driven in from the quarry face. At the Hawton quarries the former method alone is required, while at Bowbridge and Cropwell Bishop, where the workings are deeper, the two methods are used in conjunction. The supply of the mineral is abundant, and the output could be increased if warranted by the demand.

During the course of the Survey, the workings in operation within the present map were those around Newark and at Cropwell Bishop, mentioned in the last paragraph; but there have also been extensive workings near Orston (p. 51) that are temporarily in abeyance. The fibrous gypsum, with a "satiny" lustre, used for making beads and other ornaments, is obtained mainly from a seam about 6 in. thick that occurs at East Bridgford, where it is occasionally mined on a small scale.

The output of gypsum from the whole of Nottinghamshire for the last decade, including the workings in the present map along with others in Sheets 141 and 142, as recorded in the annual official "Mineral Statistics" is as follows:—

1897	-	72,370 tons	1902	-	84,659 tons
1898	-	74,667 „	1903	-	81,768 „
1899	-	77,812 „	1904	-	95,024 „
1900	-	77,492 „	1905	-	113,381 „
1901	-	76,584 „	1906	-	96,482 „

CLAY-WORKING: BRICKS, ETC.

The great expansion of Nottingham in recent times has led to the establishment of an important industry in brick-making from the Keuper and Permian Marls. As carriage is a factor of prime consequence in this business, the trade is chiefly local, and modern Nottingham is for the most part built of bricks supplied by the brickyards on the outskirts of the city. Bricks made from the Keuper Marls are usually of a mottled buff and reddish colour.

A succession of large brickfields is ranged along the edge of the Mapperley Plains, where the lower portion of the Keuper Marl affords an inexhaustible supply of the raw material. Details of some of these sections and of other pits south of Wilford and West Bridgford, will be found in Chap. IV. (pp. 45–7). The sites of the workings are indicated on the map.

The principal pits in the Permian Marl lie between Bulwell and Cinderhill, just beyond the western margin of the map.

At Newark and Bowbridge the manufacture of bricks from the Keuper Marl is carried on in connection with the gypsum quarries. There is also an old-established yard, in which the marls are worked for bricks and drain-pipes, at Harlequin, near Radcliffe-on-Trent; and the industry has been carried on, less extensively, at Southwell, Lowdham, and other places.

At Bottesford, the Lower Lias clay is worked on a small scale for making bricks, tiles and drain-pipes.

Another use to which a particular variety of the Keuper Marl has been put is for the preparation of a loam that is applied as a top-dressing to cricket pitches and lawns, as it has the effect of producing a firm surface. For this purpose the material is sent in small quantities to distant parts of the country. It is obtained chiefly from a pit in the upper part of the marl at Cotgrave and from the Harlequin brick-works near Radcliffe. Its properties appear to depend upon the essentially silty character of some of the beds in the marl, so that although fairly compact when dug, it is readily broken down to a granular loam which does not 'puddle' when wet.

SAND.

Sand for mortar mixing is obtained from the Bunter and from the sandy seams associated with the Trent gravels.

Moulding sand, used in iron-founding, is supplied by the Bunter Lower Mottled Sandstone. The quarry at *Spring Close*, Lenton (p. 33), has been worked for this purpose for about 20 years, and its product is sent to many parts of the Midlands. The same deposit is also dug at *Bobbers Mill*, in the Leen

valley; and another pit, not at present in use, occurs at *Two Mile Houses*, Basford. Sand for the same purpose, for the supply of the Bestwood Ironworks, is obtained from a pit in the lower part of the Bunter Pebble Beds at The Warren, Bestwood.

LIME AND CEMENT.

Lime and hydraulic cement of noted quality are manufactured on a large scale at Barnstone from the basal limestones of the Lias, the principal quarries at present in operation lying just beyond the southern margin of the map.

Details of the section in these quarries have already been given (p. 64); the limestone bands, interbedded with shales, that are the principal object of the excavations are named by the workmen as follows, in downward succession:—

	Thickness.
Top rummles	1 ft.
Skerries	2 „
Urrs	2 „
Running floor	1 „
Bottom rummles	2 or 3 „
Eighteen-inch	1 „
Shales { Skerries	–
Shales { Bottom floor	–

Each bed has its peculiar properties, and it is by the blending of the various beds in certain proportions that the desired properties of the lime and cement are produced. An analysis of the stone was published in a previous Memoir of the Survey ("Geology of the S.W. part of Lincolnshire," etc. [1885], p. 121).

WATER-SUPPLY.

The water-supply of Nottingham is at present obtained entirely from deep wells sunk in the Bunter formation, which, from its predominantly sandy and pebbly character, is unrivalled in its capacity for absorbing and storing the rainfall over its broad outcrop. With the rapid growth of this great manufacturing city, and with the increasing drain upon the underground water of the Bunter from the numerous wells which have tapped it for the needs of the smaller neighbouring towns, the difficulty of securing, from this source, a future supply adequate for all requirements has led the Nottingham Corporation to become participants, along with the cities of Leicester, Derby, and Sheffield, in the great Derwent Valley water-scheme; and when engineering works now in progress are completed, Nottingham will draw part of its supply from the huge reservoirs of the upper Derwent.

The earlier public wells of Nottingham were within or close to the city, but the field of operation has been gradually extended northward and north-eastward until it has passed beyond the limits of the map, the most recent sinking being at Boughton, near Ollerton, in the northerly part of the next Sheet. The wells now in operation (in Sheet 126) are situated at Basford,

Bestwood, Papplewick, and Burton Joyce, the sites being marked on the map. An old well within the city, at Park Row, is not now pumped. A detailed section of the Burton Joyce well will be found in Appendix I. (pp. 98–9). All are sunk into the Bunter, and most have been carried down to the base of this division, the following being the depth from the surface at which the Permian was reached:—Park Row, 235 ft.; Bestwood, 235 ft.; Basford, 246 ft.; and Papplewick, 275 ft. In some cases their productiveness has been increased by horizontal galleries driven out from them.[1]

Besides the wells above mentioned, two water-borings were sunk for the Nottingham Corporation, in the Dover Beck valley, at Grimesmoor, near Woodborough, and at Oxton (see Appendix, pp. 111, 117), from the former of which there is still a strong overflow of water at the surface. The scheme for the establishment of pumping-stations on these sites was, however, vehemently opposed by other public bodies and by the representatives of local private interests, and after an expensive contest, both in a Local Government Board Inquiry, held in 1896, and in a Sub-Committee of the House of Commons in 1897, this opposition was successful. In these proceedings much evidence was brought forward with respect to the lowering of the water level in the Bunter formation during recent years and the shrinkage of some of the streams and disappearance of surface water. It is stated in this evidence that the source of the Dover Beck is now at least 3 miles lower down the valley than it was within living recollection.

Newark and Southwell also obtain their organised public supply jointly from wells in the Bunter, situated at Farnsfield, in Sheet 113 (about a mile beyond the northern margin of the present map). Some deep wells have been sunk in Newark by private enterprise to obtain water from the sandy beds beneath the Keuper Marls (see p. 105).

Hucknall Torkard (in Sheet 125) is supplied from wells sunk to a depth of 125 ft. in the Bunter at Sansom Wood, 2 miles N.W. of Calverton.

The Keuper Waterstones throw out many small springs; and shallow wells sunk in these rocks usually afford sufficient water for a domestic supply, but the yield is always limited, as the impervious marly intercalations prevent free circulation; and the water is often undesirably "hard" in quality. The clustering of old villages and farmsteads along the outcrop of this formation is an indication of the ease with which water is obtainable.

In the Keuper Marls the only pervious beds are the thin bands of "skerry" sandstone. These occasionally, though rarely, throw out small springs (pp. 40, 48, 50), and they yield a limited and somewhat uncertain supply in wells. The lowland of Keuper Marl south-east of the Trent depends mainly upon this source and on shallow wells in the alluvial flats for its water.

1 For much of the information regarding the Nottingham Corporation Wells we are indebted to the courtesy of Mr. F. W. Davies, Chief Engineer of the Corporation Waterworks.

The gypsiferous belt near the top of the marls frequently holds small supplies of water, but of a hard quality, not well suited for domestic purposes, though of excellent quality for brewing.[1] On the impervious marls, as likewise on the Lower Lias clays, the shallow surface ponds in the fields retain sufficient water for cattle during normal seasons; but in a dry summer, like that of 1906, these sometimes become exhausted and cause much difficulty to the farmer.

The limestone bands of the Lower Lias retain a little water in their joints, which is held up by the underlying Rhætic shales; and the villages which line the brow of the Lias-Rhætic escarpment obtain their somewhat precarious supply from wells sunk through the limestones. Small springs occasionally issue from the escarpment along the upper boundary of the black shales of the Rhætic, the spa at Orston being the best known example.

AGRICULTURAL GEOLOGY.

On the narrow and interrupted belt of low-lying Permian strata along the western margin of the map, the soil is much modified by downwash, thin drift, and alluvium, yielding variable pebbly loam. Otherwise the Magnesian Limestone usually forms, on weathering, a brown loam that is more favourable for tillage than the stiff red clay-land of the superjacent Permian Marl, though the difference between them in this map is hardly conspicuous.

The Lower Mottled Sandstone of the Bunter has a narrow outcrop on slopes dominated by the Bunter Pebble Beds, and the sandy loam resulting from it is generally intermingled with gravelly detritus from the higher ground.

The Pebble Beds yield a very light hungry soil, sandy or gravelly according to the varying proportion of stones in the parent rock, but generally most stony on the summits of the ridges owing to the removal of the finer particles by wind and rain. Giving poor results under grass, but being easily tilled, this land, where cultivated at all, is chiefly arable. Its agricultural value is depreciated by the need for constant manuring, and by the risk of loss from droughts, so that many tracts remain under woodland and lean gorsy pasture.

The Keuper Waterstones supply a rich red loamy soil, which is the best agricultural land of the district, giving good results either under the plough or in grass, besides being the favourite site for market-gardens and orchards. Their outcrop forms a somewhat narrow belt of sloping ground north of the Trent, between the pebbly sands of the Bunter on the one side, and the stiff clays of the Keuper upland on the other.

On the Keuper Marl, which predominates greatly over the other formations in area, the prevalent soil is a heavy red clay, difficult to till and requiring subsoil drainage, but capable, under

[1] For analyses of the water from deep wells at Newark, and their comparison with the brewery waters of Burton-on-Trent, see 'The Geology of the S.W. part of Lincolnshire,' etc. (*Mem. Geol. Surv.*), pp. 121-2 and 159.

skilful treatment, of yielding good crops when the season is favourable; and it also supports much excellent pasture. The quartzose silt, which bulks largely in the composition of the marl (p. 39), is so fine in texture that the subsoil is practically impervious, but gives a more loamy character to the well-cultivated soil than can be obtained from the tougher clayey strata of the Lias. The presence of the sandy bands of 'skerry' tends still further to modify the stiffness of the soil, producing in places a comparatively light loam, particularly along the narrow belt at Hawksworth, Scarrington, and Whatton described in Chap. IV. (p. 50).

The outcrop of the Rhætic is too narrow to be of much agricultural consequence. The overlying Lower Lias, on which the Vale of Belvoir is situated, produces a heavy clay soil of dark colour. This land is modified and rendered more fertile along definite belts by the bands of limestone interbedded with the shaly clays, and also by the presence of shallow pockets of gravelly or sandy drift. It affords grass of excellent quality, and in this tract the grazing land predominates greatly over the area under the plough.

The alluvial deposits, as usual, vary greatly in composition and agricultural capabilities, according to their situation. The flats drained by the River Devon and its tributaries are occasionally sandy, as near Bottesford, but more frequently possess a stiff dark loam, with some broad tracts of thin peat, which were marshes until artificially drained. The soils of the Trent Flats, as previously stated (Chap. VII., p. 82), are partly light and gravelly, and partly heavy loam or clay. The villages are invariably placed on the gravelly tracts that rise slightly above the general level. During high floods the lower alluvial tracts are sometimes under water, and this must have been much more frequently the case before the elaborate systems of trenches were cut by which the drainage of the flats is now brought partly under control.

APPENDIX I.

SOME IMPORTANT BORINGS AND SINKINGS.

Bulwell Forest.

BORING FOR WATER.

1 in. map (N.S.) 126. 6 in. map, Notts. 38 N.W.

From J. Shipman's MS.

			Thickness. Ft.	In.	Depth. Ft.	In.
		Soil	2	0	2	0
Trias	Lower Mottled Sandstone and Bunter Pebble Beds.	Light red sandstone	50	0	52	0
		Red clay	0	2	52	2
		Red pebblestone in sandstone	1	10	54	0
		Red clay	0	2	54	2
		Light red sandstone	30	10	85	0
		Variegated sandstone	4	6	89	6
		Red clay	0	2	89	8
		Dark red sandstone	61	2	150	10
		Hard conglomerate (breccia)	1	3	152	1
		Hard dark red sandstone	7	11	160	0
Permian		Red and white clay	7	0	167	0
		Limestone	38	0	205	0
		Light bind	12	0	217	0
Coal Measures		Dark stone bind	18	0	235	0
		Yellow clay	8	6	243	6
		White spar	3	0	246	6
		Light clay	4	0	250	6
		Dark clunch	10	6	261	1
		Stone bind	4	0	265	1
		Grey stone	1	6	266	7
		White shale	4	6	271	1
		Light bind	18	0	289	0
		Dark stiff bind	28	0	317	0
		Grey stone	2	6	319	6
		White shale	8	0	327	6
		Dark bind	6	0	331	6
		Light bind	6	6	338	0
		Coal	0	2	338	2
		Strong light bind	1	10	340	0
		Coal	0	3	340	3
		Light bind	6	9	347	0
		Grey stone	1	4	348	4

Burton Joyce.

BORING FOR WATER AT BURTON JOYCE.

1 in. map (N.S.) 126. 6 in. map, Notts. 39 S.W.

Made for the Nottingham Co poration.

Communicated by the Nottingham Corporation Water Department.

Height above O.D. 64 ft.

[Abridged from the original record.]

		Thickness. Ft.	In.	Depth. Ft.	In.
	Soil	1	0	1	0
Alluvium and Trent Gravel.	Loam	2	6	3	6
	Clay	0	10	4	4
	Gravel	18	5	22	9

		Thickness. Ft. In	Depth. Ft. In.
Keuper Waterstones	Grey rock	1 3	24 0
	Marl	1 0	25 0
	Red sandstone	3 0	28 0
	Marl	13 6	41 6
	Red sandstone	3 6	45 0
	Marl	1 0	46 0
	Red sandstone	9 0	55 9
	Marl	1 0	56 0
	Red sandstone	16 0	72 0
	Marl	7 0	79 0
	Red sandstone	11 0	90 0
	Marl	7 0	97 0
	Red sandstone	10 0	107 0
	Gravel [? ; see note below]	2 0	109 0
	Red sandstone	5 0	114 0
	Marl	3 6	117 6
	Red rock	2 6	120 0
	Marl	13 6	133 6
	Red sandstone	4 0	137 6
	Marl	13 0	150 6
	Sand	1 0	151 6
	Conglomerate [Keuper Basement Bed ?]	2 0	153 6
	Gravel	0 6	154 0
Bunter	Red sandstone	12 0	166 0
	Grey rock	7 0	173 0
	Red sandstone	26 0	199 0
	Grey rock	16 6	215 6
	Red sandstone	208 6	424 0
	Red sandstone with thin beds of marl	7 0	431 0
	Red sandstone	21 0	452 0

NOTE.—We were permitted to examine specimens taken at intervals from this boring, which are preserved in the Nottingham offices of the Water Department of the Nottingham Corporation. The following notes are based on this personal examination of the specimens.

The clay at 4 ft. is a dark peaty mud underlying the usual red loam bordering the Trent flats (see p. 82). The underlying gravel, to 22 ft. 9 in., is of the usual Trent Valley type, and is mixed with sand.

The marls interbedded with sandstone, between 24 and 150 ft., are dull-red and rather sandy. Some of the sandstones are rather hard, and the 3 ft. 6 in. band at 45 ft. is yellowish. The gravel, 2 ft., at 109 ft., mentioned in the record, is not represented among the specimens. No pebbly deposit has been found at this horizon elsewhere in the district, and it seems possible that the record is based on an accidental introduction of pebbles into the boring at this point. The thick beds of red sandstone and marl immediately below this are of the usual type; the "red rock" 2½ ft., at 120 ft., is a red sandy marl. The specimen of the 13 ft. of marl at 150½ ft. is mottled, pale pinkish and greyish.

The sand at 151½ ft., at the base of the Keuper, is a brown loose sand; and the underlying 2 ft. 6 in. of conglomerate and gravel is chiefly a red sand-rock containing many pebbles, mostly small and some rather angular, but others rounded, the largest being one of quartzite about ¾ in. in diameter; there is one pebble of white quartz, but most are dark. The specimen of the "red sandstone" at the top of the Bunter is a pinkish-grey coarse sandstone, not distinctly red; and the "grey rock" immediately below is very similar to the last both in colour and texture, but rather pale.

The other specimens of the Bunter Sandstone are mostly of coarse pinkish-grey sandrock with hardly any pebbles. The 7 ft. of red sandstone with marl, at 431 ft., shows an indurated flaggy structure, perhaps slightly concretionary, and the associated marl is pinkish marl, much bruised and crushed by the boring tool. The specimen of the lowest sandstone is distinctly red in colour and rather hard and coarse-grained. G. W. L.

Edwalton.

BORING FOR COAL AT EDWALTON (see p. 18).

1 in. map (N.S.) 126. 6 in. map, Notts. 42 S.E.

Communicated by Mr. T. Potter.

Height above O.D. 95 ft.

			Thickness. Ft.	In.	Depth. Ft.	In.
		Black soil	1	0	1	0
Alluvium		Sandy loam	8	0	9	0
Trias	Keuper Marl.	Red marl and gypsum	16	8	25	8
		Grey shaly sandstone	8	0	33	8
		Red and grey marl with gypsum	27	9	61	5
		Hard grey sandstone, veins of gypsum	6	9	68	2
		Red and grey marl with gypsum	18	0	86	2
		Red and blue marl	63	0	149	2
		Grey and red marl with gypsum	86	4½	235	6½
		Red and grey sandy marl	3	9	239	3½
		Grey, and red marl with gypsum	62	3½	301	7
		Red and grey marl	48	8¼	350	3¼
		Red sandy marl	8	0	358	3¼
		Red and grey sandstone	13	4¾	371	8
		Red marl	4	10	376	6
		Red sandy marl with gypsum	22	6	399	0
	Keuper Waterstones.	Red marl	13	5½	412	5½
		Red sandy marl	5	3	417	8½
		Red and grey sandstone	11	3	428	11½
		Grey conglomerate with pebbles	0	6	429	5½
		Red and grey sandstone	12	10½	442	4
		Brown and yellow sandstone, small pebbles	5	6	447	10
		Brown and grey sandstone	1	10	449	8
	Lower Mottled Sandstone and Bunter Pebble Beds.	Grey sand with small pebbles	42	1	491	9
		Soft brown and grey sandstones with pebbles	116	0	607	9
		Conglomerate	15	0	622	9
		Red and grey mottled sandstone	77	3	700	0
		Conglomerate [Breccia, Shipman's MS.]	4	0	704	0
Coal Measures		Dark purple and grey mottled marl	9	0	713	0
		Blue, brown and purple marl	12	11½	725	11½
		Dark purple and blue marl	2	1	728	0½
		Shaly sandstone and blue bind	25	6	753	6½
		Coal	2	5	755	11½
		Parting (Dunsil)	0	2	756	1½
		Coal	0	3	756	4½
		Dark grey clunch with ironstone	2	9½	759	2
		Clunch and bind with ironstone	21	8½	780	10½
		Black shale	0	5	781	3½
		Coal	1	6	782	9½
		Fire-clay	0	1½	782	11
		Coal, Waterloo	1	11	784	10
		Shaly bind and ironstone	18	8	803	6
		Coal	1	5	804	11
		Dark clunch with ironstone balls	12	6	817	5
		Bind, clunch and ironstone	46	6	863	11
		Sandstone and sandy bind	8	5	872	4
		Blue bind and ironstone	47	2	919	6
		Coal	1	8	921	2
		Clunch	4	8	925	10
		Blue bind and ironstone	4	8	930	6
		Coal	1	2	931	8
		Dark clunch with ironstone	4	0	935	8
		Dark shale	2	2	937	10

		Thickness, Ft. In.	Depth, Ft. In.
Coal Measures.	Blue bind	9 9	947 7
	Grey sandstone	6 7	954 2
	Cank	0 5	954 7
	Grey sandstone	2 7	957 2
	Blue bind with ironstone	22 4	979 6
	Shell bed with ironstone	2 3	981 9
	Coal	0 9	982 6
	Dark fireclay	2 1	984 7
	Coal	0 8	985 3
	Dark clunch	1 9	987 0
	Blue bind and ironstone	22 1	1009 1
	Dark shale with fossils	1 7	1010 8
	Cank	0 7½	1011 3½
	Dark blue bind with ironstone	39 7½	1050 11
	Dark bind with ironstone containing shells	5 9	1056 8
	Coal	0 8	1057 4
	Stone clunch	5 4	1062 8
	Stone bind and thin sandstones	10 3½	1072 11½
	Blue and dark bind	3 9	1076 8½
	Cank	0 4½	1077 1
	Blue bind and stone bind	21 4	1098 5
	Cank	0 5	1098 10
	Blue binds	34 8	1133 6
	Cank	0 6	1134 0
	Stone binds	11 9	1145 9
	Clunch with ironstone bed	0 6½	1146 3½
	Coal, Ell	3 0	1149 3½
	Clunch with ironstone	4 9½	1154 1
	Stone clunch	10 3	1164 4
	Stone bind	11 5	1175 9
	Blue bind and ironstone	9 7½	1185 4½
	Coal, Deep Soft	3 4	1188 8½
	Strong grey clunch	4 11½	1193 8
	Blue stone bind	1 6	1195 2
	Cank	0 5	1195 7
	Blue stone bind	18 10	1214 5
	Grey sandstone	32 5	1246 10
	Brown cank	0 2	1247 0
	Grey sandstone	5 7	1252 7
	Brown cank	0 6	1253 1
	Grey sandstone	18 10½	1271 11½
	Very black shale	1 2	1273 1½
	Coal, Piper	2 10	1275 11½
	Dark clunch with ironstone	10 3½	1286 3
	Blue and black bind	14 8	1300 11
	Coal	0 6½	1301 5½
	Clunch	4 6½	1306 0
	Coal	0 9	1306 9
	Clunch	8 3	1315 0
	Dark shale with shell impressions	56 2	1371 2
	Coal, Furnace or Tupton	3 1½	1374 3½
	Dark clunch and ironstone	7 1	1381 4½
	Coal, Three-quarters	2 1	1383 5½
	Parting	0 0½	1383 6
	Coal	0 3	1383 9
	Clunch	6 9	1390 6
	Stone bind and blue bind alternating	51 11	1442 5
	Blue bind and ironstone	9 0	1451 5
	Dark shale	2 11	1454 4
	Coal, hard	0 8	1455 0
	Blue and dark shale	10 3½	1465 3½
	Coal	1 3	1466 6½
	Stone bind and blue bind with ironstone	26 7½	1493 2
	Coal, soft	3 3½	1496 5½
	Clunch	3 6½	1500 0

Gedling.

SECTION IN THE UPCAST SHAFT AT THE GEDLING COLLIERY.

1 in. map (N.S.) 126. 6 in. map, Notts 38 S.E.

Communicated by Mr. E. Parry.

Height above O.D. 185 ft.

[Abridged from MS. in Survey Office.]

			Thickness. Ft.	Thickness. In.	Depth. Ft.	Depth. In.
		Sandy soil	2	8	7	3
Trias	Keuper Waterstones	Red marl and green clay [alternating layers]	13	9	21	0
		Soft rocky marl	1	5	22	5
		Hard red rock	2	7	25	0
		Red and grey sandstone	2	4	27	4
		Rocky marl with traces of white rock	7	1	34	5
		Red and white rock, in beds	8	8	43	1
		Red and grey marly rock	30	4	73	5
		Conglomerate	2	10	76	3
	Bunter Pebble Beds.	Strong yellow sandstone with pebbles	281	10	358	1
		Strong red sandstones with grey bands	43	0	401	1
		Grey rock band	0	9	401	10
		Red sandy marl with beds of clay	2	2	404	0
		Sharp red sandstone with pebble beds	10	1	414	1
		Coarse red sandstone	16	1	430	2
		Red and grey sandstones in thin bands	6	2	436	4
		Coarse white sandstone	9	0	445	4
		Grey sandstone, pebble bed	1	3	446	7
		White stone	0	11	447	6
		Red and grey ground	13	11	461	5
Permian		Strong grey ground	46	1	507	6
		Grey grit [Permian Breccia]	0	8	508	2
Coal Measures	Etruria Marls.	Red rock, mixed ground	19	9	527	11
		Grey stone band	2	1	530	0
		Mixed ground, yellowish	5	0	535	0
		Red ironstone	3	0	538	0
		Red shale and ironstone	2	6	540	6
		Red rocks, mixed ground	19	10	560	4
		Pink bind	16	9	577	1
		Mixed ground, red, grey, and hacklish	24	11	602	0
		Red and blue shale	5	6	607	6
		Mixed ground	30	3	637	9
		Black bat and coal	0	9	638	6
		Grey binds	11	11	650	5
		Bat	0	1	650	6
		Coal	1	0	651	6
		Dirt	0	3	651	9
		Coal	0	2½	651	11½
		Dirt	0	2½	652	2
		Coal	0	6½	652	8½
		Clunch	3	8	656	4½
		Stone clunch	0	7½	657	0
		Strong grey clunch	11	9	668	9
		Grey rock	5	8	674	5
		Grey bind	9	6	683	11
		Black shale	1	2½	685	1½
		Coal	0	4	685	5½
		Black bat	0	4½	685	10
		Binds, shale and clunch	12	3	698	1
		Black bat	0	2	69	3

		Thickness. Ft. In.	Depth. Ft. In.
Coal Measures	Coal	0 6½	698 9½
	Clunch	4 1½	702 11
	Bind and ironstone	9 1	712 0
	Coal	1 6	713 6
	Clunch	2 11	716 5
	Bind and clunch	20 5	736 10
	Grey sandstone	4 9	741 7
	Grey and dark bind	8 4	749 11
	Grey rock	18 10	768 9
	Grey and blue bind	6 8	775 5
	Black bind	0 6	775 11
	Coal	1 1	777 0
	Clunch	2 7	779 7
	Stone clunch with ironstone	3 6	783 1
	Grey and dark binds	42 0	825 1
	Coal, bright	0 6	825 7
	Black bat	0 3	825 10
	Coal and bat	0 4	826 2
	Clunch	4 4	830 6
	Grey bind and ironstone	7 6	838 0
	Dark stony bind	4 10	842 10
	Dark bind [Marine bed]	1 8	844 6
	Coal	1 7	846 1
	Grey clunch, strong	5 0	851 1
	Grey bind and clunch	16 10	867 11
	Grey stone bind and rock	7 6	875 5
	Dark bind	10 11	886 4
	Clunch	9 5	895 9
	Bind and stone bind	31 3	927 0
	Dark bind and ironstone	2 2	929 2
	Strong stone clunch	1 1	930 3
	Strong brown stone	0 7½	930 10½
	Coal	1 3½	932 2
	Clunch	1 11	934 1
	Rock and stone bind	7 7	941 8
	Grey and black bind	9 0	950 8
	Dirt	0 3	950 11
	Coal	2 10	953 9
	Clunch	3 8	957 5
	Stone bind, grey and dark bind	19 11½	977 4½
	Coal	0 10	978 2½
	Black bat	0 4½	978 7
	Clunch	15 7	994 2
	Bat and clunch	7 11	1002 1
	Coal and bat	0 4	1002 5
	Clunch	0 5	1002 10
	Coal	0 7½	1003 5½
	Dark clunch	3 7½	1007 1
	Clunch and grey bind	6 11	1014 0
	Dark bind [Marine bed]	7 7	1021 7
	Black hard stone [Marine bed]	0 11	1022 6
	Dark bind	2 6	1025 0
	Coal	0 10½	1025 10½
	Grey clunch	10 10½	1036 9
	Grey and blue bind with ironstone	26 10	1063 7
	Coal	1 10	1065 5
	Grey clunch	9 0	1074 5
	Coal	0 1½	1074 6½
	Rock bind with coal streaks	1 8½	1076 3
	Bat with coal	2 2	1078 5
	Dark clunch	2 3	1080 8
	Coal (dirty)	1 0	1081 8
	Coal (bright)	0 9	1082 5
	Clunch and clod	5 1	1087 6
	Grey bind	18 1	1105 7
	Black bind	1 0	1106 7
	Rotten darker bind	1 9½	1108 4½

		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures	Coal, High Hazles	3	9	1112	1½
	Hard clunch	1	2½	1113	4
	Bind and ironstone	6	10	1120	2
	Brown stone	0	6	1120	8
	Coal	0	4½	1121	0½
	Grey clunch and bind	10	11	1131	11½
	Coal	0	7½	1132	7
	Grey clunch	1	8	1134	3
	Grey rock and bind	22	5½	1156	8½
	Black bind	1	3	1157	11½
	Black bat	0	7½	1158	7
	Coal	2	2	1160	9
	Dark clunch	1	5	1162	2
	Grey and dark bind	9	8	1171	10
	Bat and dark bind	2	3	1174	1
	Coal	1	0	1175	1
	Dirt	0	5	1175	6
	Coal	1	3	1176	9
	Coal and bat	0	7	1177	4
	Stone clunch	2	9	1180	1
	Bind and stone bind	9	5	1189	6
	Coal	0	5½	1189	11½
	Bat	0	4	1190	3½
	Clunch	4	8½	1195	0
	Stone bind and rock	31	1½	1226	1½
	Coal	2	9½	1228	11
	Fireclay	0	0½	1228	11½
	Coal	0	8	1229	7½
	Soft clunch and bat	1	2½	1230	10
	Blue bind	4	0	1234	10
	Sandstone rock	7	2	1242	0
	Grey bind and ironstone	9	5	1251	5
	Coal and bat	0	4	1251	9
	Clunch with ironstone balls	2	5	1254	2
	Coal	1	1	1255	3
	Clunch and clunchy binds	10	6	1265	9
	Grey rock and binds	4	10	1270	7
	Dark bind	0	6	1271	1
	Coal	0	2½	1271	3½
	Clunch	1	0½	1272	4
	Grey rock and bind	17	8	1290	0
	Black shale, coal and bat	0	6	1290	6
	Dark and stone clunch	2	4	1292	10
	Stone binds and rock	10	8	1303	6
	Grey bind and ironstone	7	7	1311	1
	Black shale and ironstone balls	0	9	1311	10
	Coal	0	2	1312	0
	Soft clunch	1	5	1313	5
	Dark grey sandy binds with ironstone	2	7	1316	0
	Grey bind with ironstone	2	2	1318	2
	Grey stone bind	3	8	1321	10
	Grey bind	7	4	1329	2
	Grey rock with darker streaks	0	3	1329	5
	Grey bind	10	8	1340	1
	Coal	1	2½	1341	3½
	Black bat	0	3½	1341	7
	Grey bind with ironstone balls	6	2	1347	9
	Grey bind	3	6	1351	3
	Black shale	1	5	1352	8
	Dark hard sandy bind	0	9	1353	5
	Dark rotten bind	1	11	1355	4
	Good grey bind	11	1	1366	5
	Softer bind	2	0	1368	5
	Coal	0	5	1368	10
	Clod	2	3¼	1371	1¼
	Coal	1	0¾	1372	2
	Clod full of ironstone balls	2	9	1374	11
	Coal, Top Hard (see p. 15)	2	11	1377	10
	Grey clunch	5	0	1382	10

Newark.

WELL AND BORING AT THE BREWERY OF MESSRS. J. HOLE & CO., LTD.

1 in. map (N.S.) 126. 6 in. map, Notts. 35 N.E.

Made in 1891. Height above O.D. about 55 ft.

Communicated by the Aqueous Works and Diamond Rock-boring Co., Ltd., London, S.E.

			Thickness. Ft.	In.	Depth. Ft.	In.
KEUPER	Marl.	Depth previously bored, details not given [see records of other sections referred to at foot]	—		247	6
		Red and blue marl	170	0	417	6
		Red, grey, and blue marl with gypsum	61	6	479	0
	Waterstones.	Red and grey sandy marl with gypsum	156	0	635	0
		Blue and red sandy marl	106	0	741	0
		Blue marl	20	0	761	0
		Blue and red marl, sandstone and cobbles	5	6	766	6
		Conglomerate	1	6	768	0
BUNTER		Rough sandstone and pebbles	24	0	792	0
		Red marl and sandstone	9	6	801	6

NOTE.—The records of two other deep well-sections of Newark Breweries, respectively 400 ft. and 585 ft. in depth, will be found in "The Geology of the S.W. Part of Lincolnshire," etc. (*Mem. Geol. Surv.*), 1885, pp. 148–50.

Nottingham.

BORING AT THE MIDLAND RAILWAY GOODS STATION.

1 in. map (N.S.) 126. 6 in. map, Notts. 42 N.W.

From J. Shipman's MS. Height above O.D. about 85 ft.

			Thickness. Ft.	In.	Depth. Ft.	In.
			1	4	1	4
RECENT		Made ground	13	6	14	10
		Clay and gravel	11	0	25	10
		Fine gravel	3	0	28	0
TRIAS	Lower Mottled Sandstone and Bunter Pebble Beds.	Sand rock	13	0	41	0
		Brown rock	0	6	41	6
		Sand rock	8	0	49	6
		Blue shale (? clay)	2	0	51	6
		Sand rock	89	6	141	0
		Harder sand rock with marl partings	5	0	146	0
		Sand rock with thicker layers of marl	5	0	151	0
		Conglomerate	3	6	154	6
COAL MEASURES		Pink and purple bind	4	0	158	6
		Purple and blue bind	8	8	167	2
		Varying binds with thin layers of rocky binds	48	4	215	6
		Grey rock	10	6	226	0
		Blue bind	8	3	234	3
		Smut (? coal)	3	6	237	9
		Blue bind	3	0	240	9

Owthorpe.

BORING FOR COAL (see p. 18). Flat-rope system to 1,116 ft., diamond drill below.

1 in. map (N.S.) 142. 6 in. map, Notts. 47 N.W.

Communicated by Mr. C. R. Hewitt.

Height above O.D. 200 ft.

[Abridged from MS. in Survey Office.]

In the incomplete record of this section published in "The Geology of S.W. Lincolnshire," etc. (*Mem. Geol. Surv.*) 1885, the thickness of the Bunter Pebble Beds is erroneously given as 428 ft.

			Thickness. Ft.	In.	Depth. Ft.	In.
		Blue shale [Lias]	33	0	33	0
		Black shale [Rhætic]	14	0	47	0
Trias	Keuper Marl.	Blue stone and clay [Tea-green Marls]	19	0	66	0
		Red marl and gypsum	17	0	83	0
		Grey marl	4	0	87	0
		Red marl and gypsum	8	0	95	0
		Gypsum ball	6	0	101	0
		Red marl	4	6	105	6
		Blue bind and clay	3	6	109	0
		Red marl and gypsum	11	0	120	0
		Gypsum ball	4	0	124	0
		Red marl	33	0	157	0
		Grey rock with spar	2	0	159	0
		Red marl and gypsum	23	0	182	0
		Grey freestone	2	6	184	6
		Hard red marl	4	6	189	0
		Hard grey freestone	4	6	193	6
		Red marl and gypsum	29	6	223	0
		Red and blue marl	7	6	230	6
		Hard grey rock	4	6	235	0
		Red marl and gypsum	1	8	236	8
		Hard grey sandstone	4	4	241	0
		Hard red marl	1	6	242	6
		Hard grey sandstone	4	0	246	6
		Red marl and gypsum with red and grey sandstone	19	6	266	0
		Red marl	3	0	269	0
		Blue marl and gypsum	9	0	278	0
		Grey sandstone	0	10	278	10
		Red marl and gypsum	11	2	290	0
		Very hard blue rock	3	9	293	9
		Blue bind and gypsum	2	6	296	3
		Red marl and gypsum	3	6	299	9
		Hard grey rock	2	9	302	6
		Red and blue marl and gypsum	27	0	329	6
		Hard blue and white stone	2	0	331	6
		Red and blue marl with gypsum	13	0	344	6
		Hard blue rock	1	6	346	0
		Red marl and gypsum	6	6	352	6
		Hard blue rock	10	6	363	0
		Red and blue marl with gypsum	8	0	371	0
		Hard grey rock	5	0	376	0
		Blue marl and gypsum	2	6	378	6
		Hard grey sandstone	5	6	384	0
		Red marl and gypsum	61	6	445	6
		Blue spar, marl and gypsum	19	0	464	6
		Red marl and gypsum	59	6	524	0
		Hard grey rock	1	0	525	0
		Red marl and gypsum	26	0	551	0
		Hard grey rock	11	6	562	6
		Red and blue marl with gypsum	111	6	674	0

			Thickness. Ft.	In.	Depth. Ft.	In.
Trias (*cont.*)	Keuper Waterstones	Hard grey rock	3	6	677	6
		Hard red and grey rock	16	6	694	0
		Hard red sandstone	49	0	743	
		Red and grey rock mixed with marl	30	0	773	0
		Bluish grey rock	22	6	795	6
	Bunter Pebble Beds.	Red and grey sandstone	7	0	802	6
		Red and grey sandstone with pebbles	139	6	942	0
		Stiff red clay	2	0	944	
		Red and grey sandstone with pebbles	56	0	1000	0
		Red and grey sandstone	47	0	1047	0
		Conglomerate sandstone	19	0[1066]	1069	0
Coal Measures		Red marl with red iron ore	14	0	1083	0
		Dark purple marly shale	15	0	1098	0
		Dark blue shale	18	3	1116	3
		Coal	0	3	1116	6
		Dark blue shale	19	6	1136	0
		Dark blue shale with ironstone	9	6	1145	6
		Coal	2	4	1147	10
		Blue and dark shale	43	9	1191	7
		Conglomerate	0	2	1191	9
		Light blue shale	17	9	1209	6
		Fine hard grey sandstone	6	0	1215	6
		Blue shale and ironstone nodules	57	6	1273	0
		Grey shale and stone	10	0	1283	0
		Grey sandstone	14	6	1297	6
		Blue shale	2	6	1300	0
		Coal	2	3	1302	3
		Black shale	3	9	1306	0
		Coal	1	0	1307	0
		Grey rock	14	0	1321	0
		Blue bind with ironstone boulders	19	0	1340	0
		Black and blue shale	3	3	1343	3
		Coal	0	3	1343	6
		Blue shale with ironstone	58	9	1402	3
		Coal	1	10	1404	1
		Fireclay with coal joints and ironstone balls	3	0	1407	1
		Sandy shale and shale with ironstone	22	11	1430	0
		Black shale with fossils [*Carbonicola aquilina*]	1	8	1431	8
		Blue shale and ironstone	3	9	1435	5
		Black shale with fossils [*Carbonicola aquilina*]	0	10	1436	3
		Blue and black shale with ironstone	7	4	1443	7
		Coal	1	6	1445	1
		Fireclay	3	0	1448	1
		Coal	1	4	1449	5
		Fireclay	1	4	1450	9
		Shale with ironstone	50	5	1501	2
		Coal	3	3	1504	5
		Fireclay	0	3	1504	8
		Black shale with coal joints	1	9	1506	5
		Fireclay	0	9	1507	2
		Sandstone and sandy shale	13	2	1520	4
		Blue shale with ironstone	15	5	1535	9
		Coal	0	5	1536	2
		Dark and blue shale with ironstone	7	10	1544	0
		Coal	0	8	1544	8
		Fireclay	3	6	1548	2
		Sandy shale and sandstone	24	4	1572	6
		Blue shale with ironstone [Marine bed]	38	8	1611	2

		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures	Coal	0	6	1611	8
	Sandy shale and shale with ironstone	8	1	1619	9
	Coal	0	9	1620	6
	Grey shale and sandstone	15	7	1636	1
	Blue and grey shale with ironstone	41	4	1677	5
	Coal	1	3	1678	8
	Fireclay	2	3	1680	11
	Sandy shale with ironstone	45	7	1726	6
	Coal	3	5	1729	11
	Fireclay	4	1	1734	0
	Fireclay with ironstone balls	20	1	1754	1
	Coal	2	9	1756	10
	Fireclay	0	5	1757	3
	Coal	0	7	1757	10
	Cannel	1	0	1758	10
	Black shale	2	11	1761	9
	Fireclay with balls of ironstone	2	0	1763	9
	Coal	1	2	1764	11
	Black fireclay with ironstone balls	2	6	1767	5
	Grey sandstone with black joints	1	6	1768	11
	Fireclay with ironstone	1	0	1769	11
	Grey shale, grey sandstone and ironstone	37	11	1807	10
	Very fine black shale	4	9	1812	7
	Black bass	1	0	1813	7
	Fireclay	1	0	1814	7
	Coal	0	10	1815	5
	Black shale	0	7	1816	0
	Coal	3	6	1819	6
	Fireclay	4	0	1823	6
	Dark fireclay with ironstone balls	11	4	1834	10
	Coal	1	6	1836	4
	Grey shale with two beds of sandstone	29	1	1865	5
	Coal	2	9	1868	2
	Grey sandy shale	0	3	1868	5
	Fireclay with ironstone beds	7	11	1876	4
	Coal	1	5	1877	9
	Black shale	0	6	1878	3
	Grey and black shale with ironstone	38	10	1917	1
	Dark blue shale	1	10	1918	11
	Coal	2	8	1921	7
	Dark grey shale and ironstone	20	10	1942	5
	Hard coarse grey sandstone	1	4	1943	9
	Bluish grey rock with spar joints (Igneous rock)	39	1	1982	10
	Hard coarse grey sandstone	3	5	1986	3
	Strong blue shale	1	0	1987	3
	Blue shale with ironstone	20	5	2007	8
	Coal	4	8	2012	4
	Fireclay with coal joints	0	3	2012	7
	Dark grey shale of a sandy nature	8	0	2020	7
	Beds of sandstone and grey shale	5	6	2026	1
	Grey sandstone	4	0	2030	1
	Grey shale	2	2	2032	3

Oxton.

BORING FOR COAL AT OXTON (see p. 17).

1 in. map (N.S.) 126. 6 in. map, Notts. 33 N.E.

Communicated by Captain W. Sherbrooke.

Height above O.D. about 260 ft.

[Abridged from MS. in Survey Office.]

			Thickness.		Depth.	
			Ft.	In	Ft.	In.
Trias	Lower Mottled Sandstone and Bunter Pebble Beds.	Sand and gravel	12	0	12	0
		Sandstone	15	0	27	0
		Pebbly sandstone	184	0	211	0
		Soft red sandstone, with 1 ft. breccia at base	152	0	363	0
		Grey and red soft sandstone	11	6	374	6
Permian	Marl Slates, Magnesian Limestone and Marl.	Red marl, 2 in. breccia at base	9	2	383	8
		Hard grey sandstone [sandy dolomitic limestone]	28	10	412	6
		Blue and grey sandstone [Limestone]	15	6	428	0
		Hard blue shale [with thin layers of sandy limestone]	85	6	513	6
		Hard sandstone with angular fragments [Breccia]	2	6	516	0
Coal Measures	Etruria Marl Group.	Mottled marl [chocolate, variegated, and ochreous clays]	49	0	565	0
		Strong red sandy marl	5	0	570	0
		Purple marl	12	0	582	0
		Very hard blue-grey stone	2	0	584	0
		Purple and yellow mottled marl	5	0	589	0
		Brown sandstone [chocolate, silty clay]	26	0	615	0
		Pale variegated marl and grey sandstone	60	0	675	0
		Mottled marl, mostly of the pale variegated kind	68	0	743	0
		Blue shale or marl	10	0	753	0
		Pale variegated marl	12	0	765	0
		Blue marl or shale	9	0	774	0
		Mottled marl	2	0	776	0
		Blue bind	37	0	813	0
		Fireclay with nodules and coal found in sediments	5	0	818	0
		Mottled marl	2	6	820	6
		Grey sandstone	5	6	826	0
		Brown mottled marl	15	0	841	0
		Purple and blue shales with ironstone nodules	21	0	862	0
		Red and blue mottled marl	7	0	869	0
		Black clunch	1	0	870	0
		Grey shale or fireclay	2	6	872	6
		Blue bind	5	6	878	0
		Blue sandstone with small layers of coal	24	6	902	6
		Fireclay	2	6	905	0
		Blue bind with nodules	25	6	930	6
		Grey shaly sandstone	10	6	941	0
		Black clunch	3	0	944	0
		Blue bind and fireclay (10 ft)	16	0	960	0
		Black clunch (? with coal)	1	0	961	0
		Grey shale and fireclay	4	6	965	6
		Grey sandstone	12	6	978	0
		Grey shale and black clunch	22	0	1000	0
		Grey bind and ironstone	6	0	1006	0
		Black clunch and fireclay	5	0	1011	0
		Strong grey binds	15	0	1026	0

		Thickness. Ft.	In.	Depth. Ft.	In.
	Clunch, grey bind and fireclay	8	0	1034	0
	Grey sandstone	8	0	1042	0
	Grey bind	2	6	1044	6
	Small layer of coal	0	3	1044	9
	Grey sandstone	20	3	1065	0
	Grey shale and black clunch	11	0	1076	0
	COAL (no core)	1	0	1077	0
	Fireclay	3	0	1080	0
	Grey sandstone	13	0	1093	0
	Grey bind	8	0	1101	0
	Fireclay with nodules	9	0	1110	0
	COAL	0	2	1110	2
	Fireclay	1	10	1112	0
	Grey sandstone and bind	33	0	1145	0
	Black clunch	3	0	1148	0
	Sandstone and bind	38	0	1186	0
	Blue-grey bind	31	0	1217	0
	Dark clunch with plant markings	2	0	1219	0
	Grey stone bind	46	0	1265	0
	Grey fireclay with plant markings	4	0	1269	0
	Grey stone and bind	6	0	1276	0
	Blue bind with nodules	5	0	1280	0
	Grey sandstone, hard	9	0	1289	0
	Blue bind with nodules	20	0	1309	0
	Small layer of coal	0	1	—	
	Fireclay	3	0	1312	0
	Grey bind with layers of sandstone	22	0	1334	0
	Grey shale and bind	27	0	1361	0
	Fireclay with nodules	4	0	1365	0
	Dark blue bind	28	0	1393	0
	COAL	2	0	1395	0
	Fireclay	1	0	1396	0
COAL MEASURES	Hard grey sandstone	6	0	1402	0
	Blue and black bind	7	0	1409	0
	Stone bind and sandstone	9	0	1418	0
	Grey bind and sandstone (2 ft. 6 in.)	21	6	1439	6
	COAL	0	2	1439	8
	Fireclay	1	4	1441	0
	Grey sandstone	3	0	1444	0
	Fireclay with nodules	19	0	1463	0
	Dark grey shale with ironstone	7	6	1470	6
	Grey sandstone with black streaks	3	0	1473	6
	Dark grey shale with ironstones [Marine fossils]	23	6	1497	0
	Very hard rock [blue argillaceous limestone with *Productus*, *Lingula*, goniatites]	1	6	1498	6
	Dark grey shale	1	6	1500	0
	COAL	0	4	1500	4
	Fireclay	0	8	1501	0
	Grey bind and shale with ironstone nodules	52	6	1553	6
	Hard grey sandstone	46	6	1600	0
	Black shale	1	0	1601	0
	Small seam of coal	0	3	1601	3
	Fireclay and shale	16	9	1618	0
	Conglomerate rock	6	0	1624	0
	Black and grey shale	64	0	1688	0
	Strong sandy bind	23	0	1711	0
	Dark grey shale	12	0	1723	0
	COAL	0	3	1723	3
	Fireclay	4	3	1727	6
	Grey sandstone	4	0	1731	6
	Blue bind	128	6	1860	0
	Stone clunch, nodules	1	0	1861	0
	Strong sandy bind	4	6	1865	6
	Stone clunch, nodules	7	6	1873	0

		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures	Small seam of coal	0	2	1873	2
	Fireclay	0	10	1874	0
	Strong sandy bind	13	0	1887	0
	Sandy bind and black shale	18	0	1905	0
	Fireclay	3	0	1908	0
	Grey shale	12	0	1920	0
	Sandy bind	30	0	1950	0
	Black shale and thin coal	5	3	1955	3
	Fireclay or shale	8	9	1964	0
	Grey sandstone	2	0	1966	0
	Dark grey shale, nodules	16	0	1984	0
	Strong sandy bind	25	0	2009	0
	Blue bind with nodules	17	3	2026	3
	Coal, Top Hard	4	1	2030	4
	Fireclay	1	6	2031	10
	White sandstone with black markings	5	2	2037	0
	Strong sandy bind	3	0	2040	0
	White sandstone with black partings	10	0	2050	0

Oxton.

WATER BORING, 850 yds. N.N.W. OF OXTON GRANGE.

1 in. map (N.S.) 113 (just beyond N. margin of 126). 6 in. map, Notts. 28 S.E.

Made by the Nottingham Corporation. Date 1896.

Height above O.D. 298 ft.

Communicated by the Nottingham Corporation Water Department.

		Thickness. Ft.	In.	Depth. Ft.	In.
	Soil	0	6	0	6
	Sand and gravel	2	6	3	0
Bunter	Lower Mottled Sandstone and Pebble Beds. Red sand	4	6	7	6
	Red and grey sandstone with pebbles	21	6	29	0
	Softish red sandstone with large pebbles	31	0	60	0
	Light reddish sandstone with large pebbles	27	6	87	6
	Light reddish sandstone	30	6	118	0
	Light reddish sandstone with good-sized pebbles	126	6	244	6
	Light reddish sandstone with small pebbles and marl beds intermixed	4	6	249	0
	Light reddish soft sandstone with small pebbles	54	0	303	0
	Red marl	2	2	305	2
	Light reddish sandstone with small pebbles	92	10	398	0
	Red marl	18	6	416	6
	Light reddish sandstone with large pebbles	59	6	476	0
	Mixed marls	5	0	481	0
	Light reddish sandstone with small pebbles	10	3	491	3
Permian	Mixed marls	6	11	498	2
	Magnesian limestone	2	0	500	2

Ruddington.

BORING FOR COAL AT RUDDINGTON (see p. 19).

1 in. map (N.S.) 142. 6 in. map, Notts. 46 N.W.

Communicated by Mr. G. Elmsley Coke.

Height above O.D. 100 ft.

[Abridged from MS. in Survey Office.]

			Thickness. Ft.	In.	Depth. Ft.	In.
		Soil	1	0	1	0
Glacial		Sand and gravel	2	0	3	0
		Clay, sand and gravel	4	0	7	0
Trias	Keuper Marl.	Soft red and blue marl	11	6	18	6
		Red and blue marl with gypsum veins	5	6	24	0
		Red and blue marl	76	0	100	0
		Grey shaly sandstone	4	6	104	6
		Red and blue marl with gypsum	164	0	268	6
		Grey limestone with marl joints	1	4	269	10
		Red and blue marl with gypsum veins	26	8	296	6
		Red and blue sandy marl	96	6	393	0
		Red and grey marly sandstone	35	9	428	9
	Keuper Waterstones.	Red and grey sandstone with beds of marl	13	9	442	6
		Red and grey sandy marl	21	3	463	9
		Conglomerate	3	0	466	9
	Bunter Pebble Beds.	Grey sandstone	19	11	486	8
		Red and grey pebbly sandstone	116	2	602	10
		Red and blue marl	1	0	603	10
		Red and grey pebbly sandstone	11	0	614	10
		Red and blue marl	2	0	616	10
		Red and grey pebbly sandstone	67	2	684	0
		Blue marl	1	4	685	4
		Coarse red sandstone with grey veins	2	0	687	4
Coal Measures	Lower Coal-measures.	Red and grey sandstone with beds of marl	11	8	699	0
		Red and grey sandstone with thin beds of blue shale [Wingfield Sandstones?]	58	9	757	9
		Grey sandy shale	39	3	797	0
		Blue shale	22	0	819	0
		Blue shale with ironstone bands	33	7	852	7
		Blue shale	8	0	860	7
		Blue shale with ironstone balls	18	6	879	1
		Dark blue shale	36	5	915	6
		Strong grey fireclay with ironstone balls	7	10	923	4
		Strong grey fireclay, thin veins of coal	3	0	926	0
		Dark blue shale with ironstone	16	1	942	1
		Coal, Naughton	2	5	944	6
		Dark blue clay with ironstone balls	2	6	947	0
		Dark blue shale	19	0	966	0
		Coal	1	0	967	0
		Dark fireclay	0	3	967	3
		Grey sandy shale	9	7	976	10
		Grey shaly sandstone	39	10	1016	8
		Blue shale with ironstone bands	52	9	1069	5
		Coal, Alton	3	4	1072	9
		Strong grey sandy fireclay	11	10	1084	7
		Black shale	4	7	1089	2
		Strong blue sandy shale	15	8	1104	10
		Coal	0	7	1105	5
		Black shale with coal partings	2	0	1107	5
		Strong blue sandy shale	12	0	1119	5
		Grey shaly sandstone	11	7	1131	0

		Thickness. Ft.	In.	Depth. Ft.	In.
Millstone Grit Series	Grey sandstone	18	3	1149	3
	Coarse grey sandstone, pebbly at top	64	5	1213	8
	Grey sandstone (green rock and sulphur balls)	42	0	1255	8
	Grey sandstone	12	5	1268	1
	Grey shaly sandstone	27	7	1295	8
	Blue shale with ironstone	67	1	1362	9
	Blue shale [*Lingula squamiformis*]	7	2	1369	11
	Sandy shale and sandstone	12	11	1382	10
	Blue shale and ironstone bands	28	8	1411	6
	Blue shale and ironstone bands	9	0	1420	6
	Coal	0	3	1420	9
	Fireclay, sandy	8	0	1428	9
	Grey sandstone	4	0	1432	9
	Dark stone bind	4	0	1436	9
	Grey sandstone and shaly sandstone	102	3	1539	0
	Blue shale	8	4	1547	4
	Blue sandy shale	4	8	1552	0
	Blue shaly sandstone	26	0	1578	0
	Blue sandy shale	73	2	1651	2
	Blue shale with ironstone	11	4	1662	6
	Blue shale	30	8	1693	2
	Blue shale with thin veins of coal	5	3	1698	5
	Blue shale with ironstone bands	7	0	1705	5
	Blue shale	41	3	1746	8
	Blue shale with small veins of coal	9	0	1755	8
	Blue shale	1	7	1757	3
	Coal	1	4	1758	7
	Fireclay	0	8	1759	3
	Coal	1	4	1760	7
	Fireclay	0	4	1760	11
	Blue shaly sandstone	0	3	1761	2
	Grey and reddish sandstone	109	2	1870	4

Thurgarton.

BORING FOR COAL AT THURGARTON (see p. 16).

1 in. map (N.S.) 126. 6 in. map, Notts. 34 S.E.

Communicated by Mr. G. Elmsley Coke.

Height above O.D. 57 ft.

[Abridged from MS. in Survey Office.]

	Soil	6	0	0	6
Alluvium and Trent Gravels	Blue sandy clay	4	0	4	6
	Sand and gravel mixed	7	6	12	0
	Fine sand and gravel	3	10	15	10
	Coarse gravel	3	0	18	10
	Gravel	2	2	21	0
Trias — Keuper Marl.	Blue and red clay	1	0	22	0
	Red clay	4	6	26	6
	Strong marl and gypsum	6	6	33	0
	Strong red marl	6	9	39	9
	Blue and red marl with gypsum	44	4	84	1
	Red and blue marls and hard grey sandstone	9	3	93	4
	Red marl and gypsum	20	5	113	9
Trias — Keuper Waterstones.	Red sandy marl	4	0	117	9
	Red sandy marl and gypsum with bands of sandstone	13	0	130	9
	Red and grey sandy marl	2	0	132	9
	Red sandy marl and gypsum, and bands of grey sandstone	12	10	145	7
	Red sandy marl and veins of gypsum	66	10	212	5
	Red sandy marl	4	0	216	5
	Red marly sandstone	18	2	234	7
	Red sandy marl	2	0	236	7
	Blue marly sandstone	20	4	256	11
	Coarse grey sandstone	0	8	257	7
	Red and blue sandy marl	3	6	261	1
	Grey pebbly sandstone with spar	2	8	263	9

			Thickness. Ft.	In.	Depth. Ft.	In.
Trias	Lower Mottled Sandstone and Bunter Pebble Beds.	Grey pebbly sandstone	3	10	267	7
		Grey sandstone	5	9	273	4
		Red and grey sandstone	26	11	300	3
		Reddish grey pebbly sandstone	288	3	588	6
		Red and grey sandstone	46	4	634	10
		Red sandy marl	36	2	671	0
		Red marly sandstone	4	0	675	0
		Coarse-grained red sandstone	22	2	697	2
		Red pebbly sandstone	12	0	709	2
		Coarse red brecciated conglomerate	7	0	716	2
		Red sandstone	15	0	731	2
		Red sandy marl with streaks of grey sandstone	5	1	736	3
		Red marly sandstone with grey sandstone	2	11	739	2
		Red marl with sandstone partings	18	0	757	2
Permian	Marl Slates, Magnesian Limestone, and Marl.	Blue shale	2	0	759	2
		Red and blue marl	7	0	766	2
		Blue shale with hard bands	2	7	768	9
		Hard grey sandstone, jointy	0	7	769	4
		Blue shale	16	11	786	3
		Blue shale with sandstone partings	6	3	792	6
		Gritty calcareous sandstones with plant markings	13	0	805	6
		Gypsum	0	6	806	0
		Calcareous gritty sandstone	0	8	806	8
		Blue shale	1	0	807	8
		Close-grained grey sandstone	1	10	809	6
		Close-grained sandstone with blue shale partings	12	0	821	6
		Close-grained sandstone	2	0	823	6
		Calcareous gritty sandstone [*Productus horridus*]	2	6	826	0
		Strong blue shale [*Productus horridus*], Breccia at base	24	6	850	6
Coal Measures	Keele Group.	Red and grey sandstone	24	6	875	0
		Red and grey sandy shale	3	0	878	0
		Chocolate and purple shale	11	6	889	6
		Purple, reddish and grey sandstone	69	6	959	0
		Reddish grey sandstone [*Pecopteris arborescens*]	25	6	984	6
		Red and brown marl	8	0	992	6
		Red and grey sandy shale	3	6	996	0
		Red and blue sandy mottled marl	4	6	1000	6
		Variegated marl	35	6	1036	0
		Black shale and [ironstone]	2	0	1038	0
	Newcastle Group.	Grey sandstone	5	6	1043	6
		Blue shale [*Alethopteris aquilina*]	6	0	1049	6
		Coal	0	3	1049	9
		Strong blue shale or clay [*Alethopteris aquilina, Lepidostrobus*]	2	3	1052	0
		Grey sandstone	1	0	1053	0
		Grey sandstone with streaks of coal	4	0	1057	0
		Strong blue shale with limestone [nodules]	17	0	1074	0
		Light blue shale	10	0	1084	0
		Light blue shale with limestone balls	7	0	1091	0

			Thickness. Ft.	In.	Depth. Ft.	In.
	Etruria Marl Group.	Red and blue shale, very rotten	38	6	1129	6
		Deep red marl	20	8	1150	2
		Green conglomerate [Espley Rock]	1	0	1151	2
		Strong red marl	2	6	1153	8
		Green conglomerate [Espley Rock]	0	6	1154	2
		Strong red marl	10	7	1164	9
		Strong blue sandstone [Espley Rock]	9	8	1174	5
		Strong red marl	17	6	1191	11
		Blue shaly sandstone	5	0	1196	11
		Red and mottled marl	16	7	1213	6
		Blue shaly sandstone	2	0	1215	6
		Blue conglomerate [Espley Rock]	8	6	1224	0
		Red marl	13	3	1237	3
		Green sandy shale	4	6	1241	9
		Mottled shale	4	9	1246	6
		Grey shaly sandstone	8	6	1255	0
		Pale-coloured variegated marl	11	0	1266	0
		Grey marly sandstone	22	9	1288	9
		Strong red and blue marl	0	9	1289	6
		Grey shaly sandstone	8	3	1297	9
		Grey sandstone [Espley Rock]	3	0	1300	9
		Mottled marl	16	6	1317	3
		Blue marl	4	0	1321	3
		Yellow marl	3	3	1324	6
		Grey sandstone	16	0	1340	6
		Grey sandy shale	3	6	1344	0
		Grey and mottled marl	13	6	1357	6
		Blue shale	10	6	1368	0
		Mottled marl	6	0	1374	0
		Blue sandy shale	12	0	1386	0
Coal Measures		Blue shale with ironstone	4	10	1390	10
		Coal, soft	0	10	1391	8
		Fireclay	9	0	1400	8
		Blue sandy shale and ironstone balls	11	0	1411	8
		Dark blue shale	1	8	1413	4
		Coal, joint, thickness doubtful	0	2	1413	6
		Dark grey fireclay, plant remains	2	6	1416	0
		Blue sandy shale with ironstone	2	0	1418	0
		Grey sandstone	7	0	1425	0
		Blue sandy shale and ironstone	3	8	1428	8
		Blue shale and ironstone	27	0	1455	8
		Grey sandstone	8	7	1464	3
		Blue sandy marl and ironstone	2	0	1466	3
		Grey sandstone with coal streaks	8	0	1474	3
		Dark blue shale with ironstone balls	7	3	1481	6
		Dark fireclay with red patches at middle	10	0	1491	6
		Blue sandy shale with ironstone	17	6	1509	0
		Fireclay, strong	3	0	1512	0
		Blue sandy shale	26	1	1538	1
		Fireclay	4	1	1542	2
		Blue shale	16	4	1558	6
		Grey shaly sandstone	3	6	1562	0
		Blue shale	11	0	1573	0
		Dark blue or black shale	8	0	1581	0
		Blue shale	4	0	1585	0
		Coal and bat (wild gas coal?)	0	3	1585	3
		Strong fireclay and ironstone balls	2	6	1587	9
		Grey shaly sandstone	9	6	1597	3
		Strong fireclay and ironstone	2	0	1599	3
		Dark blue shale	2	0	1601	3
		Grey sandstone	3	0	1604	3
		Blue shale	9	0	1613	3
		Black shale	1	0	1614	3

		Thickness. Ft.	In.	Depth. Ft.	In.
Coal Measures	Coal	0	6	1614	9
	Fireclay and ironstone balls	10	0	1624	9
	Shaly sandstone with coal streaks	27	9	1652	6
	Dark blue shale and ironstone	12	6	1665	0
	Blue shale and ironstone [marine fossils]	7	6	1672	6
	Fireclay	6	0	1678	6
	Grey shaly sandstone	4	10	1683	4
	Dark shale and sandstone partings	8	0	1691	4
	Blue shale and ironstone balls	25	9	1717	1
	Grey sandstone	16	10	1733	11
	Black shale	9	1	1743	0
	Dark blue shale	7	6	1750	6
	Fireclay	2	0	1752	6
	Grey shaly sandstone and shale	33	6	1786	0
	Blue shale and ironstone	62	9	1848	9
	Blue sandy shale	5	0	1853	9
	Grey sandstone	5	0	1858	9
	Blue shale and ironstone	17	6	1876	3
	Black shale	0	3	1876	6
	Grey sandstone	6	6	1883	0
	Blue sandy shale and ironstone	20	10	1903	10
	Blue shale and ironstone	3	0	1906	10
	Fireclay	1	0	1907	10
	Grey shaly sandstone	7	0	1914	10
	Blue shale	4	2	1919	0
	Dark grey sandstone	2	0	1921	0
	Blue shale and ironstone	7	8	1928	8
	Black shale	0	6	1929	2
	Fireclay and ironstone	10	7	1939	9
	Blue shale and ironstone	6	10	1946	7
	Soft fireclay and ironstone	11	1	1957	8
	Blue shale and ironstone	24	7	1982	3
	Grey sandstone	17	9	2000	0
	Blue shale	13	0	2013	0
	Strong fireclay	2	0	2015	0
	Blue sandy shale	11	6	2226	6
	Strong fireclay and ironstone balls	3	0	2029	6
	Blue sandy shale	16	0	2045	6
	Grey sandstone	11	0	2056	6
	Blue shale and ironstone	7	0	2063	6
	Grey shaly sandstone	10	6	2074	0
	Blue shale and ironstone	13	0	2087	0
	Grey sandstone	64	0	2151	0
	Blue shale and ironstone	15	0	2166	0
	Blue sandy shale	15	6	2181	6
	Strong fireclay	1	0	2182	6
	Blue shale and ironstone	1	10	2184	4
	Strong fireclay	2	0	2186	4
	Blue shale and ironstone	31	2	2217	6
	Grey sandstone	3	0	2220	6
	Blue shale	8	6	2229	0
	Bored, but no core	8	6	2237	6

Woodborough.

BORING FOR WATER AT GRIMESMOOR, near WOODBOROUGH.

1 in. map (N.S.) 126. 6 in. map, Notts. 34 S.W.

Made for the Nottingham Corporation. Date 1895.

Communicated by the Nottingham Corporation Water Department.

Height above O.D. 116 ft.

[Abridged from the original record.]

		Thickness. Ft.	In.	Depth. Ft.	In.
	Soil	0	8	0	8
Alluvium	Sand and gravel	2	11	3	7
	Clay	0	2	3	9
	Sand and gravel	4	6	8	3
	Sandy clay and gravel	4	3	12	6
Keuper Waterstones	Soft red marl	5	6	18	0
	Variegated marl and pebbles	11	3	29	3
	Soft sandstone	2	6	31	9
	Soft red marl with pebbles	3	3	35	0
Bunter — Lower Mottled Sandstone and Pebble Beds.	Sand and fine gravel (Water burst in and continued to increase down to 60 ft. 6 in.)	0	8	35	8
	Soft marl with thin beds of sand and gravel	17	0	52	8
	Soft sandstone and sand	4	4	57	0
	Soft sandstone, chiefly grey, with pockets of sand and small gravel	63	0	120	0
	Red marl	1	3	121	3
	Soft sandstone with sand and gravel	94	9	216	0
	Red sandstone	149	0	365	0
	Red marl	1	0	366	0
	Red sandstone	23	0	389	0
	Red sandstone and bands of marl	4	8	393	8
	Variegated clay with thin bands of sandstone	25	8	419	4
	Red sandstone	44	10	464	2
Permian	Variegated marl	1	6	465	8
	Red sandstone	2	0	467	8
	Variegated sand and clay	4	4	472	0
	Magnesian limestone with bands of marl	7	0	479	0

APPENDIX II.

LIST OF THE PRINCIPAL WORKS ON THE GEOLOGY OF THE DISTRICT.

1719. Stukely, Dr. W.—An account of the Impression of the almost Entire Sceleton of a large Animal in a very hard Stone, lately presented to the Royal Society, from Nottinghamshire. *Phil. Trans.*, vol. xxx., pp. 963–8 [description of reptilian remains from the Lower Lias at Elton].

1835. Sedgwick, A.—On the Geological Relations and Internal Structure of the Magnesian Limestone and the Lower Portions of the New Red Sandstone Series in their range through Nottinghamshire, etc. *Trans. Geol. Soc.*, ser. 2, vol. iii., pp. 37–124, and supplement, p. 239.

1841. Bailey, T.—On the Gravel Deposits in the neighbourhood of Basford [letter]. *Proc. Geol. Soc.*, vol. iii., p. 411–3.

1855 and 1879. Hull, E.—1 in. Geological Map, Old Series, Quarter-sheet 71 S.E. *Geol. Surv.* 2nd ed., with additions by W. T. Aveline, in 1879.

1858 and 1879. Aveline, W. T., E. Hull, and T. R. Polwhele.—1 in. Geological Map, O.S., Quarter-sheet 71 N.E. *Geol. Surv.* 2nd ed., with additions by W. T. Aveline in 1879.

1861. Aveline, W. T.—Horizontal Section. Sheet 61. No. 1, From the Erewash Valley . . . to Toot Hill south of Bingham [with accompanying "Explanation," 6 pp]. *Geol. Surv.*

1861 and 1880. Aveline, W. T.—The Geology of the Country around Nottingham. (Quarter-sheet 71 N.E., with small portions of 71 S.E. and S.W.) *Mem. Geol. Surv.* 2nd ed. in 1880.

1866. Stevenson, W.—The Building Materials of Nottinghamshire ; being a series of practical Essays illustrating the Geological . . . bearings. *Republished from the "Building News" with additional notes.* Lond. and Nottm.

1868. Wilson, E.—On Faults and Contortions in Strata [letter, with figs., and descrip. of faults in Keuper at Nottingham]. *Geol. Mag.*, vol. v., pp 341–3.

1869. Hull, E.—The Triassic and Permian Rocks of the Midland Counties of England. *Mem. Geol. Surv.*

1871. Report of the Geological Committee in *Rep. of the Commissioners appointed to inquire into the several matters relating to Coal in the United Kingdom*, vol. i., pp. 135–8 and 143 : and vol. ii., pp. 441–3, etc., with maps and sections.

1874. Irving, Rev. A.—On the Geology of the Nottingham District. *Geol. Mag.*, dec. ii., vol. i., pp. 314–9 : also more fully in *Proc. Geol. Assoc.*, vol. iv. (1875), pp. 45–89.

Woodward, H. B.—Rhætic Beds near Newark, *Geol. Mag.*, dec. ii., vol. i. [letter], p. 480.

1876. Irving, Rev. A.—Some recent Sections near Nottingham. *Quart. Journ. Geol. Soc.*, vol. xxxii., pp. 513–5.

Wilson, E.—On the Permians of the North-east of England (at their southern margin), and their relations to the under and overlying Formations. *Quart. Journ. Geol. Soc.*, vol. xxxii., pp. 533–7.

1877. Aveline, W. T.—The Magnesian Limestone and New Red Sandstone in the neighbourhood of Nottingham. *Geol. Mag.*, dec. ii., vol. iv , pp. 155–6, and [letter] 380.

Irving, Rev. A.—On the so-called "Permian" and the New Red Sandstone Formations. *Geol. Mag.*, dec. ii., vol. iv., pp. 309–12.

Shipman, J.—Conglomerate at the base of the Lower Keuper. *Geol. Mag.*, dec. ii., vol. iv., p. 497–9.

Wilson, E.—A short Notice of a new Exposure of Rhætics near Nottingham. *Quart. Journ. Geol. Soc.*, vol. xxxiii., *Proc.*, pp. 1–2.

———The Magnesian Limestone and New Red Sandstone in the neighbourhood of Nottingham. *Geol. Mag.*, dec. ii., vol. iv. [letter], pp. 238–40

1878. SHIPMAN, J.—Some new features in the Geology of East Nottingham *Mid. Nat.*, vol. i., pp. 18–20, 30–33.

1879. WILSON, E., and J. SHIPMAN.—On the Occurrence of the Keuper Basement Beds in the Neighbourhood of Nottingham. *Geol. Mag.*, dec. ii., vol. vi., p. 532-5.

1880. SHIPMAN, J.—Notes on the Alluvial and Drift deposits of the Trent Valley near Nottingham. *Ann. Rep. Nottm. Nat. Soc.* for 1879, pp. 15–32; also republished, with additions, as separate pamphlet, Nottm.

1881. BROWN, J.—Description of some Borings on the Clifton Estate, and of the sinking of the Clifton Colliery, Nottingham. *Trans Chesterfield and Derbysh. Inst. Eng.*, vol. viii., pp. 345-64.

1882. HARRISON, W. J.—Geology of Nottinghamshire, No. 28 in *Geology of the Counties of England and . . . Wales*, pp. 207–11. Lond.

WILSON, E.—On the Rhætics of Nottinghamshire. *Quart. Journ. Geol. Soc.*, vol. xxxviii., pp. 451–6.

————On a discovery of fossil Fishes in the New Red Sandstone of Nottingham [abstr.]. *Rep. British Assoc.* for 1881, p. 637 and in *Mid. Nat.*, vol. v. (1882), pp. 45–6; see also *Quart. Journ. Geol. Soc.*, vol. xliii. (1887), pp. 542–3.

1883. JUKES-BROWNE, A. J.—On the relative ages of certain River-valleys in Lincolnshire [discusses Rivs. Trent and Devon]. *Quart. Journ. Geol. Soc.*, vol. xxxix., pp. 596–610.

SHIPMAN, J.—The Alluvial and Drift Deposits of the Leen Valley. *Mid. Nat.*, vol. vi., pp. 76–9, and 109–15. (See also "The Geology of the Parish of Lenton," 1884.)

————On a Boulder from the Bunter Pebble Beds near Nottingham [abstr.]. *Mid. Nat.*, vol. vi., p. 264.

WILSON, E.—The Rhætic Rocks of Nottinghamshire. *Mid. Nat.*, vol. vi., pp. 193–9.

1884. SHIPMAN, J.—Geology of the Parish of Lenton. Chap. xvii., pp. 408–44 in *The History of the Parish and Priory of Lenton* (Bemrose, London); also pub. as separate reprint. Nottm.

————Geological Map of the Borough of Nottingham, in *Report of Medical Officer of Health, Nottingham*, for 1883. Also published separately, Nottm.

1885. JUKES-BROWNE, A. J., and W. H. DALTON.—The Geology of the South-west part of Lincolnshire with parts of Leicestershire and Nottinghamshire. (Explanation of Sheet 70.) *Mem. Geol. Surv.*

1885 and 1894. METCALFE, A. T.—A sketch of the Geology of Nottinghamshire, in White's *Directory and Gazetteer of Notts.* [2nd ed contains a Bibliography to 1893.] Sheffield.

1886. DEELEY, R. M.—The Pleistocene Succession in the Trent Basin. *Quart. Journ. Geol. Soc.*, vol. xlii., pp. 437–80.

HOLLOWAY, W. H., and others.—1 in. Geological Map. Old Series. Sheet 70 (in two editions; 'Solid' and 'Drift'). *Geol. Surv.*

1887. GASCOYNE, R.—On the eastern extension of the Leeds and Nottingham Coalfield. *Trans. Mid. Inst. of Min., etc., Eng.*, vol. x.

NEWTON, E. T.—On the Remains of Fishes from the Keuper of Warwick and Nottingham. *Quart. Journ. Geol. Soc.*, vol. xliii., pp. 537–40.

1890. SHIPMAN, J.—The Geology of Nottingham. *Trans. Nottm. Nat. Soc.* for 1889 (37*th Ann. Rep.*), pp. 26-37.

1891. METCALFE, A. T.—The Geology of Nottinghamshire, in C. Brown's "*History of Nottinghamshire.*" London.

1892. BLAKE, J. F.—Report of Excursion to Nottingham. *Proc. Geol. Assoc.*, vol. xii., pp. 386–92.

1893. SHIPMAN, J., R. M. DEELEY, and Rev. J. M. MELLO.—The Geology of Nottinghamshire, in "A contribution to the Geology and Natural History of Nottinghamshire." Edited by Prof. J. W. CARR. *Handbook for Brit. Assoc. Meeting at Nottingham*, 1893, pp. 4–33 [contains a Bibliography, up to 1892]. Nottm.

1893. Shipman, J.—Six Geological Horizontal Sections illustrating the Structure and Relations of the rocks around Nottingham. *Nottm.*

Woodward, H. B.—The Jurassic Rocks of Britain. Vol. iii., The Lias of England and Wales (Yorkshire excepted). Chap. vi., etc. *Mem. Geol. Surv.*; also Bibliography of Jurassic Rocks to 1895, in *ibid.* vol. v.

1894. Shipman, J.—The Geology of the Leen Valley. *Trans. Nat. Assoc. Coll. Managers*, vol. v., p. 89.

1895. Metcalfe, A. T.—The Gypsum Deposits of Nottinghamshire and Derbyshire. *Trans. Nottm. Nat. Soc.* for 1894, pp. 19–29.

Shipman, J.—The Coal-measures of the Leen Valley. *Trans. Nottm. Nat. Soc.* for 1894. Also published as separate reprint. Nottm., 1905.

1896. Coke, G. E.—The Southern Limit of the Nottinghamshire Coalfield. *Trans. Fed. Inst. Mining Eng.*, vol. xi., pp. 339–44.

Coke, G. E., J. W. Carr, and W. W. Watts.—Excursion to Nottingham and Leicester. *Proc. Geol. Assoc.*, vol. xiv., pp. 430–3.

Gresley, W. S.—The Yorkshire and Nottingham Coalfield: Geological Suggestions relative to its eastward extension beneath the Permian and Secondary strata into Lincolnshire. *Trans. Fed. Inst. Min. Eng.*, vol. xi., pp. 143–50.

1897. Strangways, C. Fox-.—Geology of the London Extension of the Manchester, Sheffield and Lincolnshire Railway. Part I., Annesley to Rugby. *Geol. Mag.*, dec. iv., vol. iv., pp. 49–59.

1900. Bonney, Rev. T. G.—The Bunter Pebble-beds of the Midlands and the Source of their Materials. *Quart. Journ. Geol. Soc.*, vol. lvi., pp. 287–306.

1901. Gibson, W.—On the Character of the Upper Coal-measures of North Staffordshire, Denbighshire, South Staffordshire, and Nottinghamshire; and their relation to the Productive Series. *Quart. Journ. Geol. Soc.*, vol. lvii., pp. 251–65.

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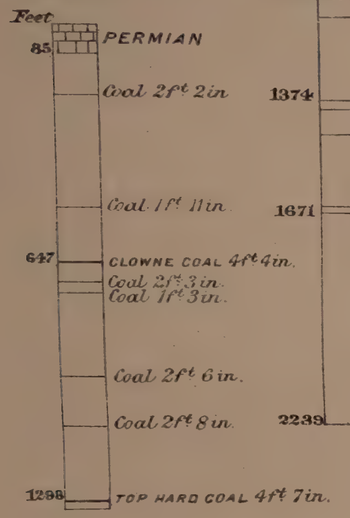
Sections of Shafts and Borings
shewing the extension of the Coalfield beneath the Permian & Trias Formations

Scale One Inch = 500 Feet.

By W. Gibson D.Sc.

THURGARTON BORING
57.OD.

LINBY COLLIERY
290.OD.



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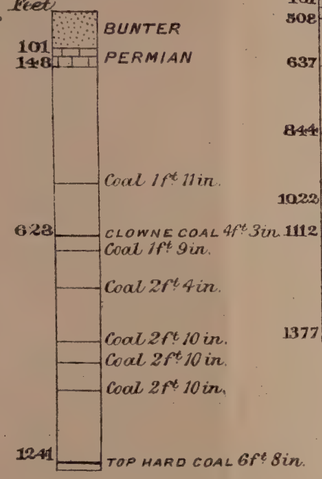

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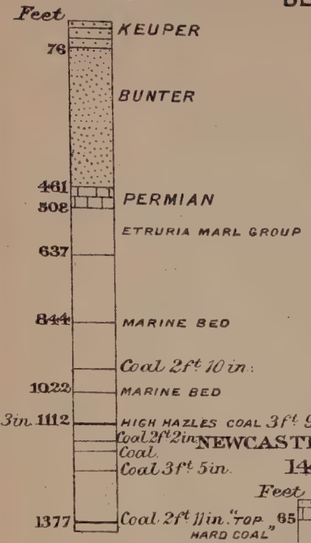

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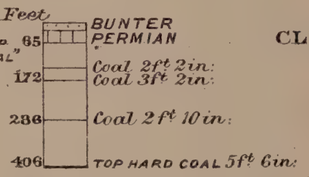

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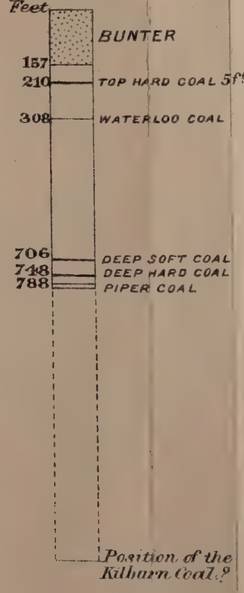

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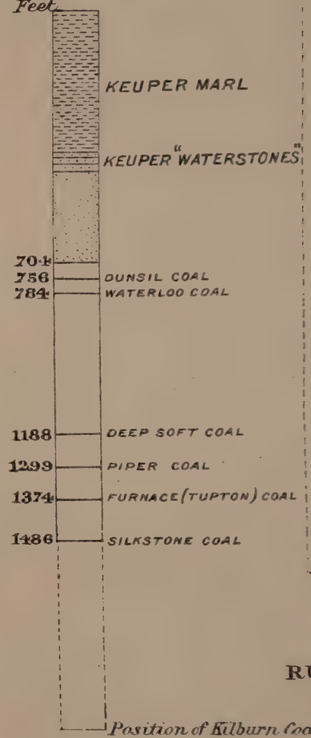

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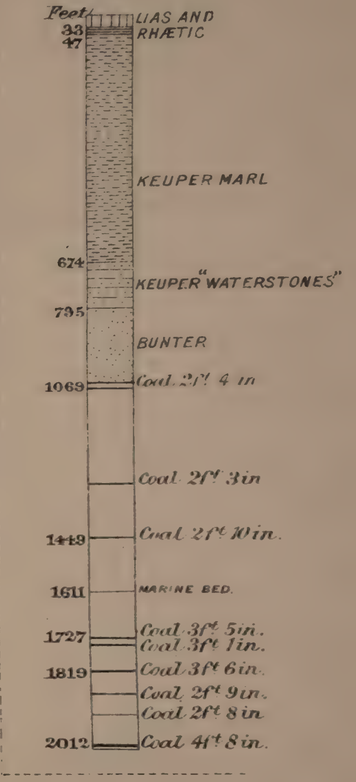

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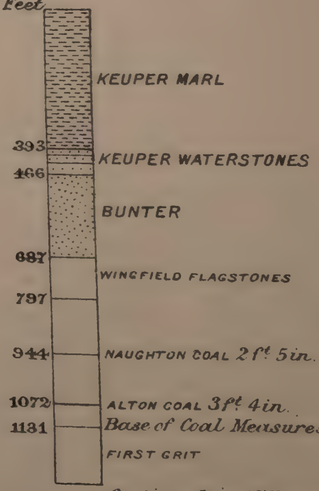

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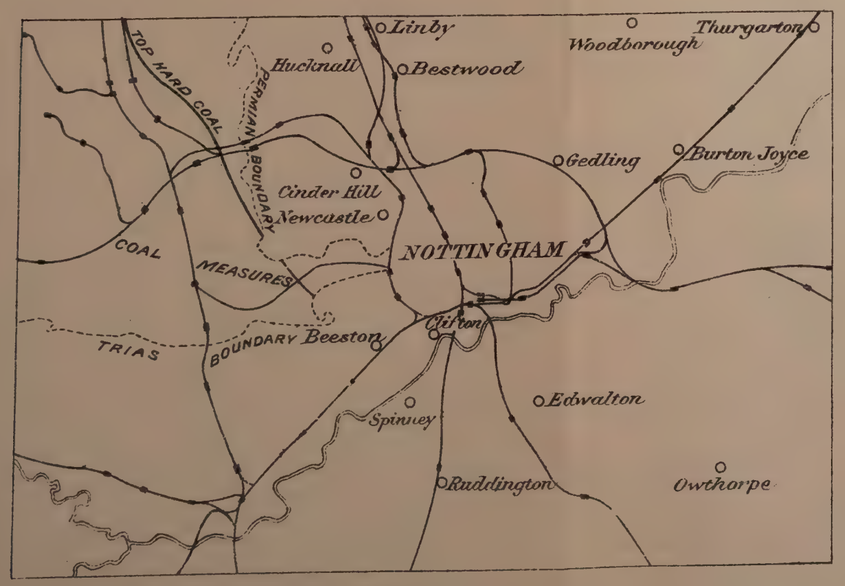

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